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Research Paper PNW-261
October 1979

Poisoning and Trapping Pocket Gophers to protect Conifers in Northeastern Oregon

by Glenn L. Crouch and Larry R. Frank

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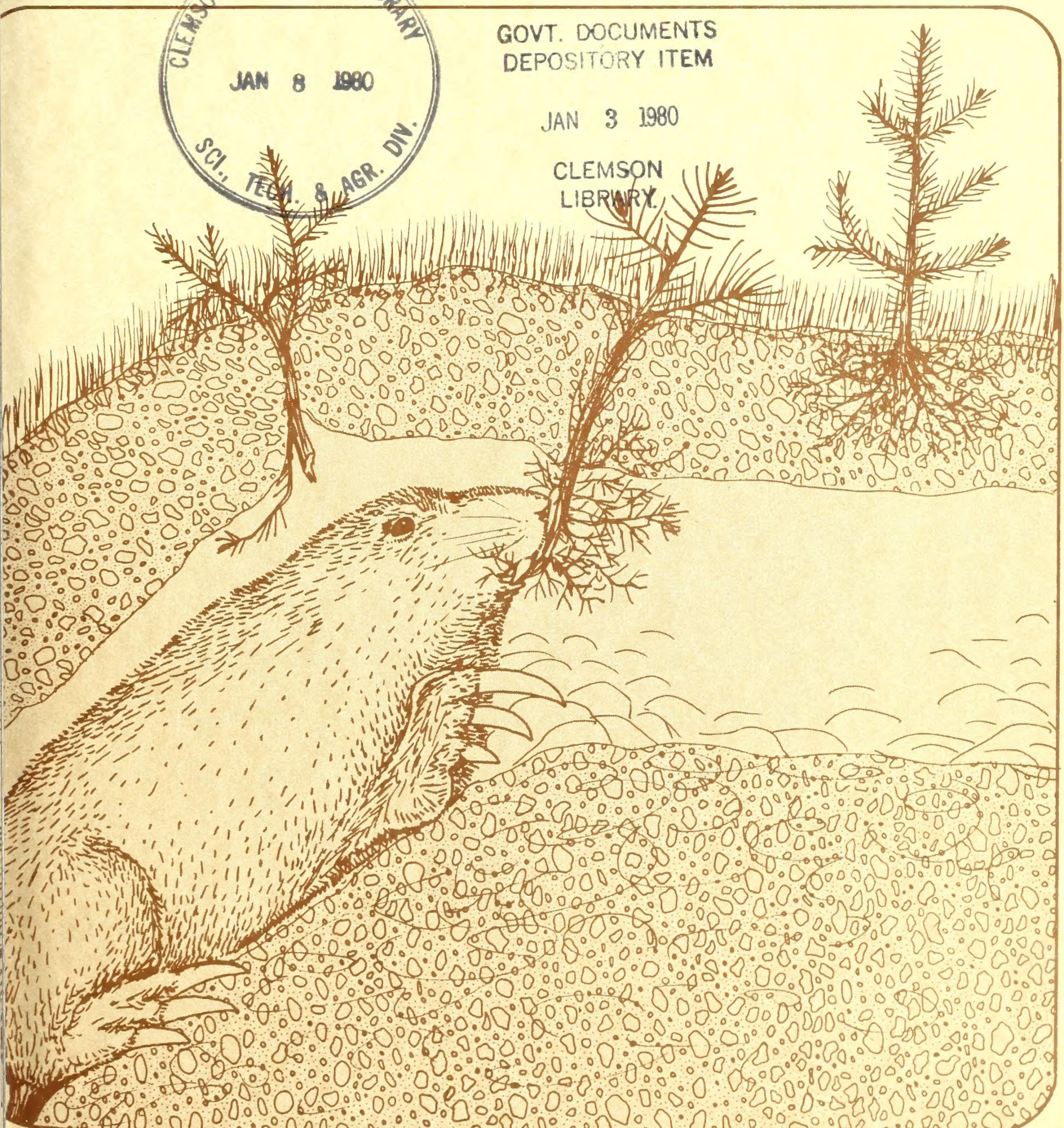

Authors

At the time this research was conducted, GLENN L. CROUCH was principal plant ecologist at the Pacific Northwest Forest and Range Experiment Station, Olympia, Washington. He is now principal research wildlife biologist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

LARRY R. FRANK is forestry technician at Walla Walla Ranger District, Umatilla National Forest, Walla Walla, Washington.

Poisoning and Trapping Pocket Gophers To Protect Conifers in Northeastern Oregon

Reference Abstract

Crouch, Glenn L., and Larry R. Frank
1979. Poisoning and trapping pocket gophers to protect conifers in northeastern Oregon. USDA For. Serv. Res. Pap. PNW-261, 8 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Poisoning or trapping pocket gophers was employed on mixed conifer plantations in northeastern Oregon to reduce the rodent's damage to young trees. Single treatment of either procedure was ineffective, but two applications, about 2 weeks apart, resulted in significant reductions in mound building and damage to trees.

KEYWORDS: Poisoning (-animal pests, trapping (-forest pest control, gophers (pocket), rodent control.

RESEARCH SUMMARY

Research Paper PNW-261

1979

For many years, pocket gophers (*Thomomys* sp.) have been known to kill planted and natural conifer seedlings and saplings on clearcut blocks in the Blue Mountains in northeastern Oregon. Foresters there have reported annual tree losses caused by gophers in single species and mixed plantations. Although accurate assessments are not available, losses have been judged severe enough to warrant periodic programs of poisoning or trapping to reduce numbers of gophers, thereby controlling damage to the trees.

Unfortunately, the efficacy of such treatments to protect trees has not been evaluated adequately in the Blue Mountains or on other Western forests where similar practices of control are employed. This 2-year study was conducted to determine whether the established operational poisoning and trapping program used on the local National Forest protected young conifers and whether trapping was as effective as poisoning.

The first year, poisoning and trapping were conducted by Forest Service crews according to procedures regularly followed with no preferential treatment of study sites. Clearcut blocks were treated once during the summer, with the time of application regulated by the crew supervisor. This procedure proved ineffective and was modified the following year when blocks were treated twice, with 2 weeks or more between treatments.

The single treatments of poisoning or trapping applied the first year did not reduce tree damaghe or mortality from gophers, but either treatment applied twice the following year resulted in a significant reduction in both damage and mortality from these animals.

Annual losses from gophers in the Blue Mountains appeared lower than those we have observed elsewhere in the Pacific Northwest. But even these rates of attrition, if uncontrolled, could eventually eliminate planted trees and delay restocking unless the sites are periodically replanted or naturally regenerated.

Trapping was more expensive than poisoning in hours expended, and even though traps can be used repeatedly, their initial high cost compared with that of poisoned bait seems to further justify poisoning as the more economical procedure.

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For many years, pocket gophers (*Thomomys* sp.) have been known to kill planted and natural conifer seedlings and saplings on clearcut blocks in the Blue Mountains in northeastern Oregon.

Gophers are widely distributed in this area. Even cursory examinations of most natural openings or clearcut blocks will reveal mounds of earth from gopher excavations, or ribbons of soil (casts) pushed into the snow by gophers in winter. Abundance of mounds or casts is generally considered an indication of gopher abundance.

Ranger Districts on the Umatilla National Forest, Oregon, have reported annual tree losses caused by gophers in single species and mixed plantings of ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*), western larch (*Larix occidentalis*), lodgepole pine (*P. contorta*), and Engelmann spruce (*Picea engelmannii*) (Crouch 1969). Although accurate assessments are not available, losses have been judged severe enough to warrant periodic poisoning or trapping programs to reduce number of gophers, thereby controlling damage to the trees.

Unfortunately, the efficacy of such treatments to protect trees has not been evaluated adequately in the Blue Mountains or on other Western forests where similar control practices are employed. Increasing demand for prompt reforestation after logging and burning plus mounting concern about benefits and costs of programs to control damage by animals requires appraisal of current gopher control procedures. Also, apprehension about control methods using toxicants justifies comparative evaluation to determine if trapping is an acceptable alternative to poisoning.

Our study was conducted to determine whether the established operational poisoning and trapping programs used on the Umatilla National Forest protected young conifers from gophers and whether trapping was as effective as poisoning.

Study Area and Methods

The study area was located on the Walla Walla Ranger District of the Umatilla National Forest at elevations ranging from 4,500 to 5,000 feet. Plant communities and soil characteristics of this mixed conifer forest were described by Hall (1973).

Four replications of three clearcut blocks each were selected on the western part of the Ranger District. A replication consisted of blocks of similar size, slope, year of logging, tree stocking levels, and current gopher activity levels. The 3 blocks within replications averaged 14, 20, 25, and 40 acres among the 4 areas.

TREATMENTS

In 1973, one clearcut block in each replication was randomly assigned for poisoning, trapping, or to be left untreated. In 1974, the same treatments were again randomized among blocks, without regard to assignments the previous year. Poisoning and trapping were conducted by a Forest Service crew that routinely did this work. The crew consisted of four or five seasonal employees with the junior author serving as field supervisor; they generally worked from snowmelt in June to snowfall in October.

In 1973, poisoning and trapping were conducted according to procedures regularly followed on the Ranger District with no preferential treatment of study sites. Traps were set or poisoned bait (a spoonful of strychnine-treated,[1] steam-crushed oats) was placed in an open tunnel of a gopher's main burrow system. Area treatment was accomplished by spacing crew members about 50 feet apart along one side of a block and having them move across the area, setting traps or dispensing bait where freshly built gopher mounds were encountered.

Blocks were treated once in 1973, with the time of application regulated by the crew supervisor. In 1974, blocks were either trapped or poisoned twice, with 2 weeks or more between treatments. The more intensive treatment in 1974 was devised after the procedure used the previous year proved ineffective.

EVALUATION

Control measures were evaluated by comparing among treatments the percentages (frequencies) of plots occupied by casts or mounds produced by gophers, and percentages of damage to stems or roots and mortality of trees. Sample data were obtained from 0.01-acre circular plots systematically established 1 per acre at 210-foot intervals on parallel compass lines beginning about 100 feet from uncut timber and extending across the blocks. Plot centers were marked with numbered wooden stakes, and the four trees nearest plot centers were also staked.

In 1973, plots were installed and existing mounds counted and erased in mid-August. Treatments were applied at three of the four locations by early September, and plots and trees were reinventoried about 2 weeks later. The fourth area was not treated until October; these blocks were not included in the 1973-74 analysis.

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[1] The pesticide reported on here was registered for the use described at the time this publication was prepared. Since the registration of pesticides is under constant review by State and Federal authorities, a responsible State agency should be consulted as to the current status of this pesticide.

In 1974, blocks were inspected in early July soon after snowmelt, and treatments were assigned. They were examined again in mid-September, about 2 weeks after the final treatments were applied, and finally in June 1975.

DATA ANALYSES

Data were subjected to analyses of variance with arcsin transformations of percentage values. Tukey's test was used to separate treatment means where appropriate (Snedecor 1961).

Results

GOPHER ACTIVITY

Pretreatment cast frequencies in May 1973 and mount frequencies in August were nearly identical (table 1). Mound frequencies in

Table 1--Pocket gopher activity before and after poisoning or trapping on clearcut blocks in the Blue Mountains in Oregon

Activity indicator[1]	Treatment[2]					
	1973-74			1974-75		
	None	Poison	Trap	None	Poison	Trap
	--Percent of 0.01-acre plots occupied--					
Before treatment:						
Casts, May[3]	44	44	44	55	58	61
Mounds, August	74	77	77	--	--	--
After treatment:						
Mounds, September	56	50	46	66a	34b	41b
Casts, June	61	58	53	65	57	56

[1] Means within the same activity indicator and year class followed by the same letter or no letter are not significantly different (P = 0.05).

[2] Blocks were poisoned or trapped once in 1973 and twice in 1974.

[3] Cast counts in 1973-74 were made prior to the start of this study.

September, after poisoning or trapping, were also similar, indicating that the treatments did not reduce gopher activity. In 1974, pretreatment cast frequencies were somewhat greater than in 1973, but again were nearly identical among blocks within each group (table 1). After two poisoning or trapping treatments in July and August, mound frequencies were significantly lower on the treated areas than on the controls. But again, cast frequencies were not different among treatments the next spring (1975) indicating that treated areas had been reoccupied.

DAMAGE AND MORTALITY

Despite high pretreatment levels of gopher activity on all blocks, damage to trees was low compared to other areas in Oregon (Crouch 1971, Hooven 1971, Barnes 1974) (table 2). Virtually all damage occurred in winter, and it was similar to that found elsewhere by the senior author. Some small trees were removed by gophers, some were cut off at ground level and their tops were removed, and roots were severed and removed from others. Larger trees were usually barked, with root damage also evident.

Table 2--Damage and mortality to conifers from pocket gophers on poisoned or trapped clearcut blocks in the Blue Mountains in Oregon

Item[1]	Treatment[2]					
	1973-74			1974-75		
	None	Poison	Trap	None	Poison	Trap
Trees per acre, number	246	270	250	236	246	225
Tree height, cm	49	44	47	59	58	62
Damage by gophers, %	7	5	7	12a	3b	4b
Mortality from gophers, %	5	3	3	9a	3b	3b
Total mortality, %	8	9	8	13	8	9

[1] Means within the same item and year followed by the same letter or no letter are not significantly different (P = 0.05).

[2] Blocks were poisoned or trapped once in 1973 and twice in 1974.

The single poisoning or trapping treatments applied in 1973 did not reduce damage or mortality from gophers (table 2). But this lack of control was expected because mound frequencies, our indicators of gopher abundance, had not been reduced by the treatments (table 1). Poisoning or trapping twice, 2 weeks apart in 1974, reduced mound frequencies about 50 percent and resulted in a significant reduction in damage and mortality caused by gophers.

On untreated blocks, gophers were the major single cause of mortality in both years, but they were not the most important factor on treated areas in either year (table 2).

Gophers showed no apparent preferences among the six species of conifers comprising the sample trees (table 3). Smaller trees were damaged more often than larger ones, and losses were greatest among western larch seedlings interplanted in 1972 on blocks at two of the study sites.

Table 3--Damage to conifers by pocket gophers on clearcut blocks in the Blue Mountains in Oregon

Species	Number of trees	Percent damaged
True fir (grand and subalpine firs)	390	5
Western larch	294	9
Ponderosa pine	103	8
Engelmann spruce	88	4
Lodgepole pine	71	4
Douglas-fir	22	5

Discussion

Poisoning or trapping twice in a single year significantly reduced losses from gophers, even though overall damage was relatively low. We cannot, however, predict whether the percentage reduction in gopher activity we attained would result in areas where initial mortality from gophers was greater.

Mound frequencies based on counts made 2 to 4 weeks after poisoning or trapping provided satisfactory predictions of treatment effects. Lack of significant reductions in mound frequencies after treatments in 1973 correctly predicted that no reductions in gopher damage or mortality would occur during the next winter. Significant reductions in mound frequencies after treatments in 1974 were followed by reductions in damage and mortality measured in June 1975. Although no evaluations were subsequently made, the high cast frequencies in June 1975 may have indicated that reductions in tree mortality were temporary, and that continued treatment might have been needed to maintain control of gopher populations and reduce tree losses.

Trapping was more expensive than poisoning in hours expended (table 4), and even though traps can be used repeatedly, their initial high cost compared with that of poisoned bait seems to further justify poisoning as the more economical procedure.

Table 4--Time expended poisoning or trapping pocket gophers on clearcut blocks in the Blue Mountains in Oregon

Year	Treatment[1]	
	Poison	Trap
	----Worker-hours per acre[2]----	
1973	1.4a	2.0a
1974	1.4a	3.0b

[1] Treatments applied once in 1973 and twice, about 2 weeks apart, in 1974.

[2] Within years, means followed by the same letters are not significantly different (P = 0.05).

Certainly the application of poisoned grain, even underground, constitutes some hazard to nontarget animals and therefore may be undesirable in some instances. But gopher traps also present hazards. We have caught weasels (*Mustela* spp.), deer mice (*Peromyscus maniculatus*), chipmunks (*Eutamius* spp.) and kangaroo rats (*Dipodomys* sp.) in them.

Time expended in application of either treatment is only one measure of cost. Expenses also must include those that pay for surveys to determine where control is needed, transportation and housing of workers, and materials to protect workers handling poisoned bait.

Annual losses from gophers in the Blue Mountains appear lower than those we have observed elsewhere in the Pacific Northwest. But even these rates of attrition could eventually eliminate planted trees and delay restocking unless the sites are replanted or naturally regenerated.

Foresters experiencing slow losses of trees from gophers face difficult decisions regarding control programs. Judgments must be made on whether observed losses will materially deter or preclude reforestation, or if survival of plantings plus natural recruitment will adequately restock clearcut blocks within prescribed time limits. Such judgments require annual monitoring of plantations and decisions to control losses before stocking approaches minimum acceptable levels. To delay control will often result in need for replanting, including costly site preparation procedures.

Our results indicate that trapping can substitute for poisoning to control damage by gophers although trapping appears to be more expensive and no more effective than poisoning.

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Crouch, Glenn L., and Larry R. Frank
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KEYWORDS: Poisoning (-animal pests, trapping (-forest pest control, gophers (pocket), rodent control.

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U.S. Department of Agriculture
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Pacific Northwest Forest
and Range Experiment Station
Research Paper PNW-262
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Illustrated Key to Introduced and Common Native Parasites of Larch Casebearer

Roger B. Ryan

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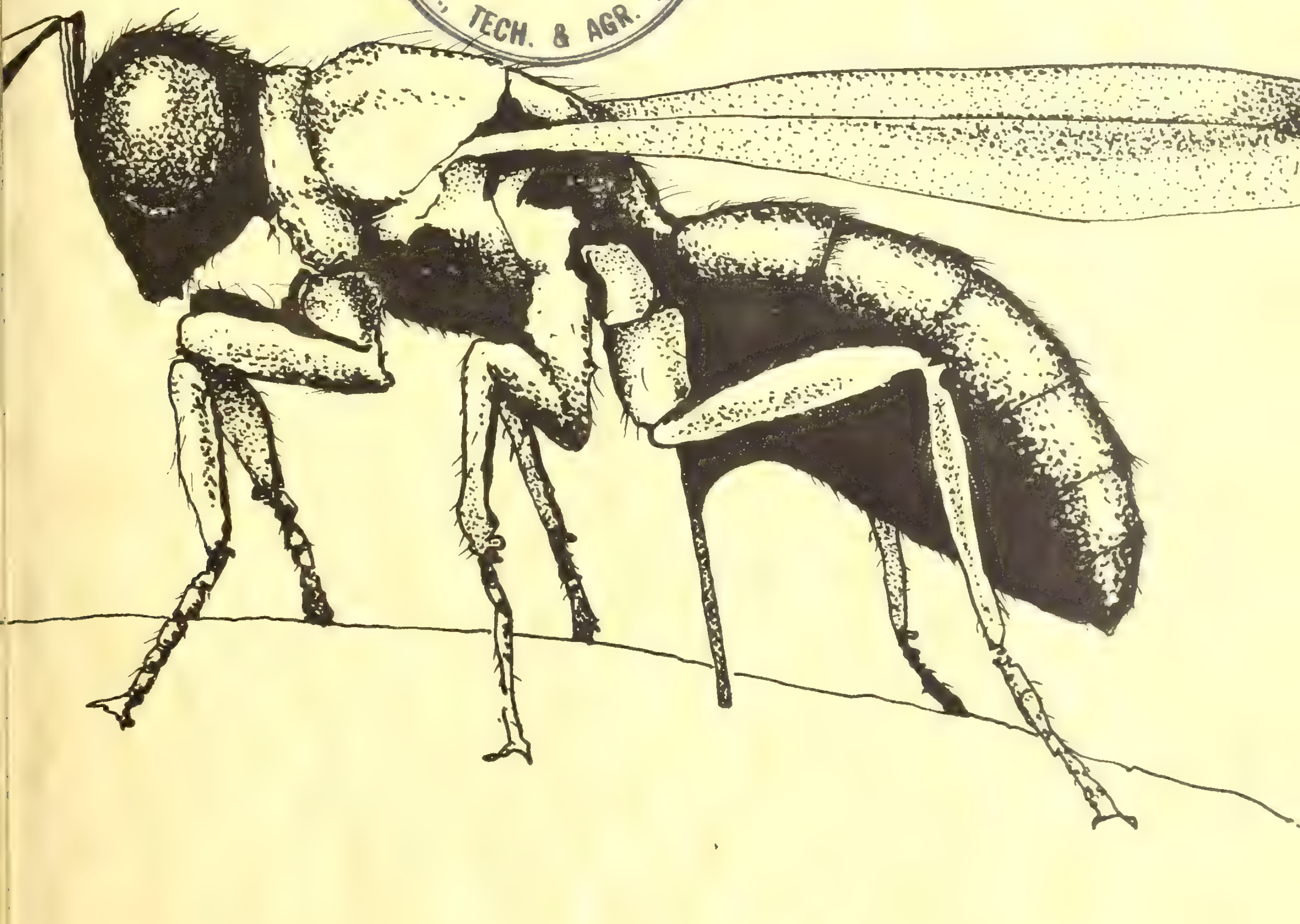

ILLUSTRATED KEY TO INTRODUCED AND COMMON NATIVE PARASITES OF LARCH CASEBEARER

Reference Abstract

Ryan, Roger B.
1979. Illustrated key to introduced and common native parasites of larch casebearer. USDA For. Serv. Res. Pap. PNW-262, 12 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

A key to introduced parasites of larch casebearer and commonly recovered native parasites features labeled and highlighted line drawings to facilitate identification.

KEYWORDS: Parasites (insect)(-forest pest control, larch casebearer, *Coleophora laricella*, keys (insect parasites).

RESEARCH SUMMARY

Research Paper PNW-262

1979

Line drawings are featured in a key to identify the following species of introduced larch casebearer parasites: *Agathis pumila* (Ratz.), *Diadegma laricinellum* (Strobl), *Chrysocharis laricinellae* (Ratz.), *Dicladocerus westwoodii* Westw., *D. japonicus* Yshm., *Necremnus metalarus* (Walk.), *Elachertus argissa* (Walk.), and *Cirrospilus pictus* (Nees). Also included in the key are some genera and species of native parasites commonly recovered from larch casebearer samples from the Western United States.

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INTRODUCTION

The larch casebearer, Coleophora laricella (Hbn.), has been the object of a biological control program in the Western United States since 1960 when the European parasite, Agathis pumila (Ratz.), was colonized in northern Idaho. To date, seven species of exotic parasites from Europe and Japan have been released in the West: A. pumila, Chrysocharis laricinellae (Ratz.), Dicladocerus westwoodii Westw., D. japonicus Yshm., Necremnus metalarus (Walk.), Elachertus argissa (Walk.), and Diadegma laricinellum (Strobl) (Denton 1972, Ryan and Denton 1973, Ryan et al. 1975 and 1977). One other parasite, Cirrospilus pictus (Nees), previously released in the East, has not been released in the West because of its wide host range and sometimes hyperparasitic behavior.

A large part of the present biological control effort is devoted to evaluating the effectiveness of the introduced parasites. Evaluation requires collecting samples of casebearers from many localities where parasites have been released and, as a means of comparison, from areas where parasites have not yet become established.

Samples collected at the time of casebearer pupation in June are reared to obtain adult insects, and all parasites are identified to verify the presence or absence of introduced species and their densities relative to casebearer densities. The ability to categorize the thousands of adults emerging from numerous samples is therefore necessary. The key that follows will assist in the task of identification for those not familiar with parasite taxonomy. Technical language has been held to a minimum. Line drawings, illustrating diagnostic features, are included for key characters.[1]

By working through the steps of the key, you will arrive at a tentative identification that will probably be correct. The key will perhaps best serve to determine what a particular parasite is not, however. Because identification of parasite species requires considerable experience, consult an expert for verification in critical cases. Additional help may also be obtained by consulting the works of Graham (1959), Marsh (1963, 1971), Peck et al. (1964), Sloan and Coppel (1965), Townes (1969), and Yoshimoto (1973, 1976).

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[1] Supplementary characteristics of size and color are sometimes given. These characteristics are subject to seasonal variation and may be different if collections are made other than during the time of casebearer pupation in June.

KEY TO LARCH CASEBEARER PARASITES

1. Forewings with several veins and closed cells (fig. 1), or wingless; antennae long and thin, with 16 or more uniform segments. 2
   Forewings with reduced venation and no closed cells (fig. 2); antennae with long basal segment, then a series of not more than 10 shorter segments (fig. 24, 25) 9

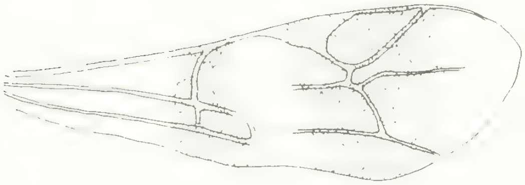

Figure 1.--Gelis sp.

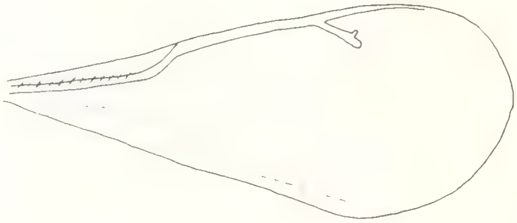

Figure 2.--Dicladocerus sp.

2. (1) Wingless, or wings with two broad smoky bands (fig. 1). . . . . .Gelis sp. (Ichneumonidae)
   Wings clear or smoky, but not banded. 3

3. (2) Forewing with cells M_1 and M_2 separate (fig. 3, 4, 11, 12) (Ichneumonidae). 5
   Forewing with cells M_1 and M_2 confluent (fig. 5, 6) (Braconidae) 4

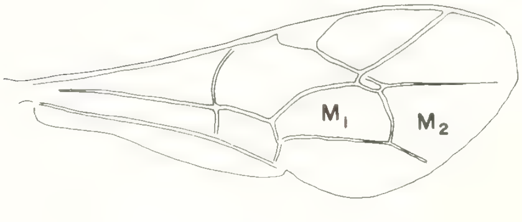

Figure 3.--Scambus sp.

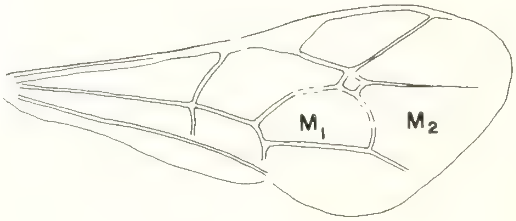

Figure 4.--Itoplectis sp.

4. (3) Radial vein of forewing reaches wing margin well before wing apex, making cell R_1 narrow (fig. 5); face with clypeus not emarginate . . . . .Agathis pumila
   Radial vein meets wing margin near apex, making cell R_1 broader (fig. 6); face with cylpeus roundly emarginate, forming a circular opening above mandibles . . . . .Bracon sp.

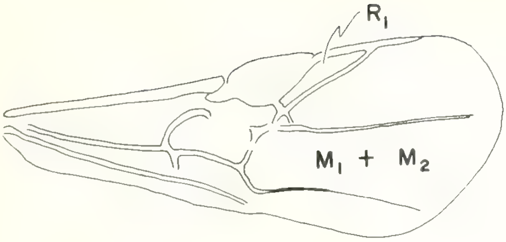

Figure 5.--*Agathis pumila*

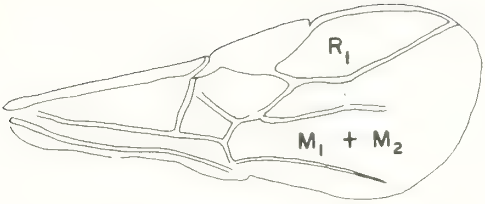

Figure 6.--*Bracon* sp.

5. (3) First abdominal segment broad at base (dorsal view)(fig. 7,
arrow), no more than about 1-1/2 times longer than broad . . . 6
First abdominal segment narrow at base (fig. 8, arrow), about
3 times longer than maximum width. 7

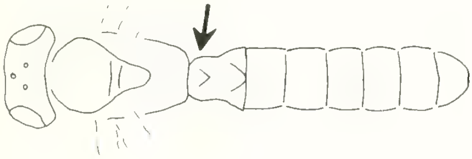

Figure 7.--*Itoplectis* sp.

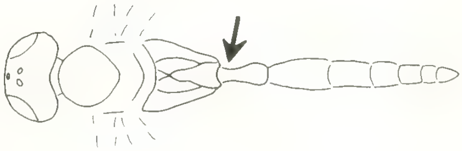

Figure 8.--*Diadegma laricinellum*

6. (5) Femora and tibiae of front legs white; middle tibiae uniformly
white; extreme base of hind tibiae white . . . . . *Scambus* sp.
Femora and tibiae of front legs amber; middle tibiae banded light
and dark; extreme base of hind tibiae dark . . .*Itoplectis* sp.

7. (5) Clypeus distinctly set off by a groove (fig. 9, arrow); face with
light colored markings, at least around eyes . *Pristomerus* sp.
Clypeus not distinct (fig. 10); face completely dark, although
mandibles may be light 8

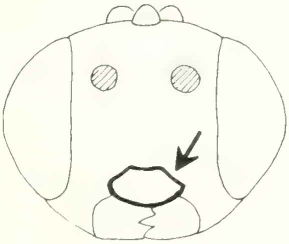

Figure 9.--*Pristomerus* sp.

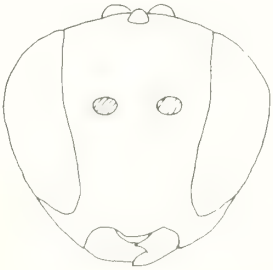

Figure 10.--*Diadegma laricinellum*

8. (7) Forewing with areolet present, although not complete (fig. 11); first tergite with a lateral longitudinal groove in front of the spiracle; front coxae of male dark . . . Diadegma laricinellum
Areolet absent (fig. 12); first tergite without a lateral longitudinal groove in front of the spiracle; front coxae of male light . . . . Campoplex sp.

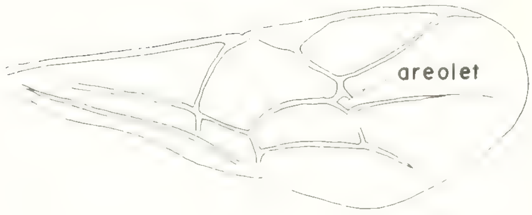

Figure 11.--Diadegma laricinellum

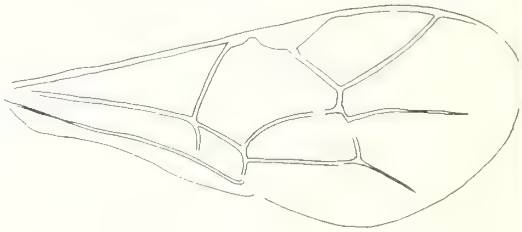

Figure 12.--Campoplex sp.

9. (1) Hind femora greatly enlarged (fig. 13), apposable with tibiae toothed and jawlike (Chalcididae). 10
Hind femora not greatly enlarged or apposable with tibiae (fig. 14). 11

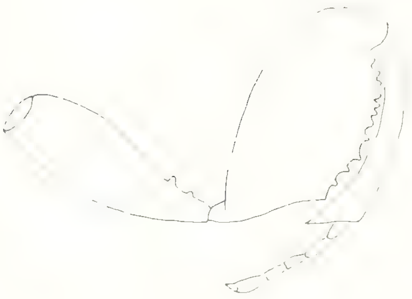

Figure 13.--Spilochalcis sp.

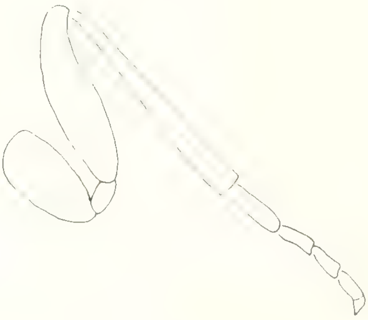

Figure 14.--Necremnus metalarus

10. (9) Face of male with light-colored, inverted V-shaped area (female rarely found on larch casebearer) . . . . Spilochalcis albifrons
Face of male entirely light-colored . . . . . Spilochalcis leptis

11. (9) Five tarsal segments (Pteromalidae) 12
Four tarsal segments (Eulophidae) 13

12. (11) Antennae inserted below middle of face (fig. 15); male green with bright yellow band on abdomen, yellow legs and yellow antennae with black club; female uniformly bronze-green . *Mesopolobus* sp.
Antennae inserted at midline of face (fig. 16); purplish color . . . . *Habrocytus* sp.

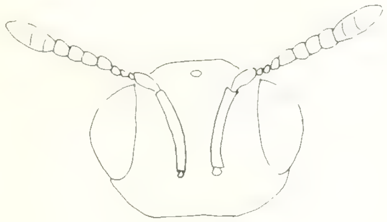

Figure 15.--*Mesopolobus* sp.

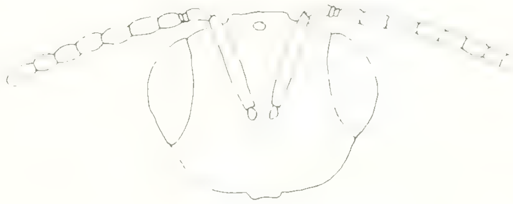

Figure 16.--*Habrocytus* sp.

13. (11) Scutellum with two longitudinal dorso-lateral grooves (may be indicated merely by the pattern of surface sculpturing) (fig. 17, arrow). 14
Scutellum without two longitudinal dorso-lateral grooves (fig. 18) 22

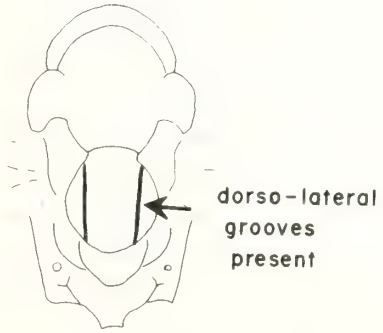

Figure 17.--*Dicladocerus westwoodii*

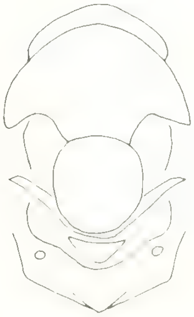

Figure 18.--*Necremnus metalarus*

14. (13) Parapsidal grooves complete, reaching scutellum (fig. 19). . . 15
Parapsidal grooves incomplete, not reaching scutellum (fig. 20). 18

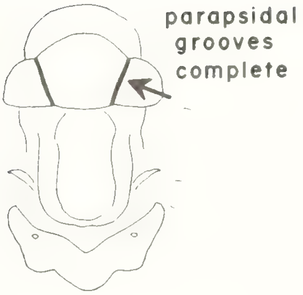

Figure 19.--*Elachertus* sp.

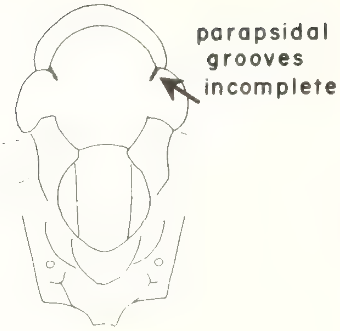

Figure 20.--*Dicladocerus* sp.

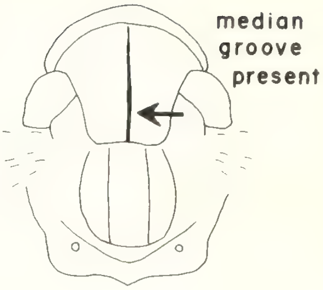

Figure 21.--*Tetrastichus* sp.

15. (14) Mesoscutum with median, longitudinal groove, at least posteriorly (fig. 21); forewing with postmarginal vein very short or absent, much shorter than radial vein (fig. 22). . . . . *Tetrastichus* sp.
Mesoscutum without median, longitudinal groove; forewing with postmarginal vein as long as or longer than radial vein (fig. 23) 16

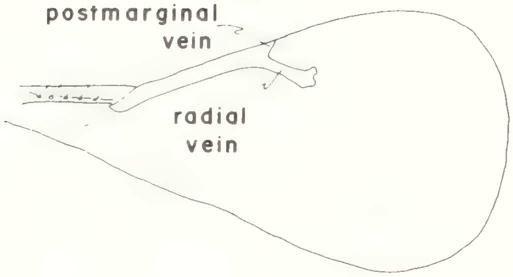

Figure 22.--*Tetrastichus* sp.

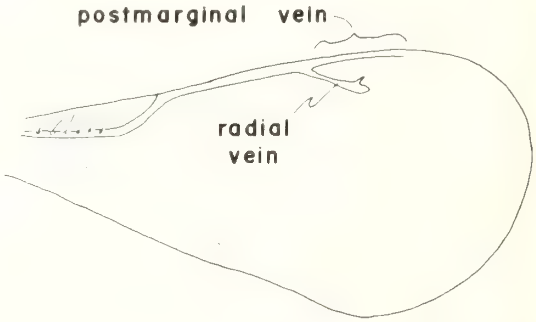

Figure 23.--*Elachertus argissa*

16. (15) Thorax brown, marked with yellow; antennae with two funicular segments (between ring segments and club)(fig. 24) . . . . *Cirrospilus pictus*
Thorax black; antennae with four funicular segments 17

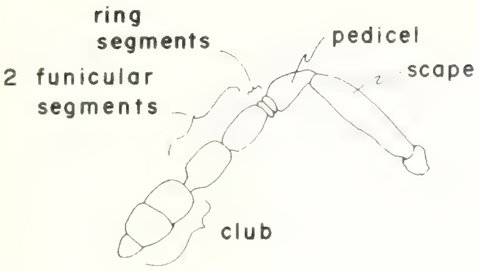

Figure 24.--Cirrospilus pictus

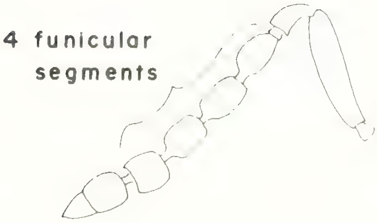

Figure 25.--Elachertus argissa

17. (16) Posterior margin of mesoscutum almost straight (fig. 26, arrow); head and thorax black with greenish reflections; abdomen brownish. . . . . Elachertus argissa
Posterior margin of mesoscutum distinctly angled (fig. 27, arrow); head and thorax without greenish reflections. . . Elachertus sp.

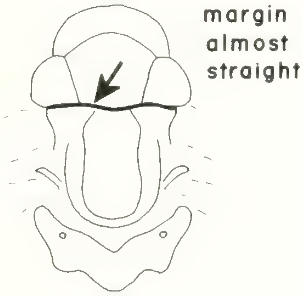

Figure 26.--Elachertus argissa

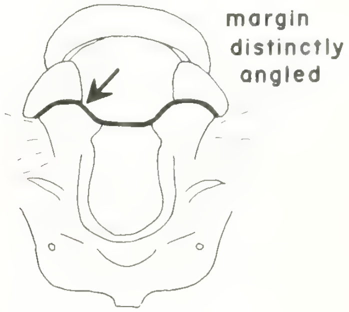

Figure 27.--Elachertus sp.

18. (14) Males. 19
Females. 21

19. (18) Funicular branches long, the distal one reaching well past the end of the next segment (fig. 28) . . . Dicladocerus westwoodii
Dicladocerus japonicus
Funicular branches shorter, the distal one reaching no farther than the end of the next segment (fig. 29, 30). 20

20. (19) Funicular branches medium length, the distal one terminating about even with the end of the next segment (fig. 29) . . . . *Dicladocerus nearcticus*

Funicular branches short, the distal one reaching at most to the middle of the next segment (fig. 30) . . . .*Dicladocerus pacificus*

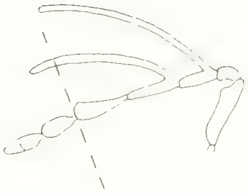

Figure 28.--*Dicladocerus japonicus*

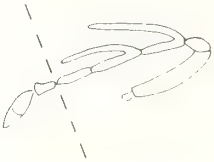

Figure 29.--*Dicladocerus nearcticus*

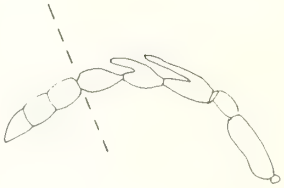

Figure 30.--*Dicladocerus pacificus* (after Yoshimoto)

21. (18) Medial carina of propodeum much higher anteriorly than posteriorly; when viewed from the side, an imaginary line projecting the top edge of the medial propodeal carina connects more with the line of the scutellum than that of the dorsellum (fig. 31). . . . . *Dicladocerus westwoodii*
Dicladocerus japonicus

Medial carina of propodem of nearly equal height throughout its length; when viewed from the side, an imaginary line projecting the top edge of the medial propodeal carina connects more with the line of dorsellum than that of the scutellum (fig. 32) . . . .*Dicladocerus nearcticus*
Dicladocerus pacificus

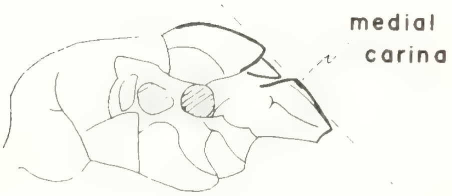

Figure 31.--*Dicladocerus japonicus*

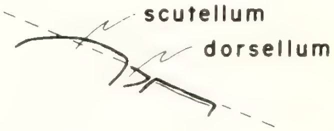

Figure 32.--*Dicladocerus nearcticus*

22. (13) Forewing with three lines of hairs radiating from stigma (fig. 33, arrow) . . . . Euderus sp.
Forewing without three lines of hairs radiating from stigma (fig. 34, 35) 23

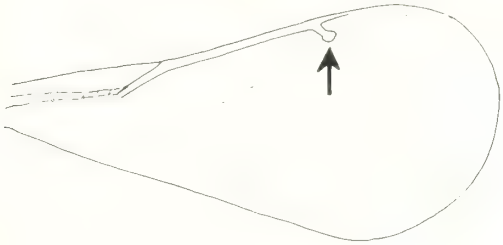

Figure 33.--Euderus sp.

23. (22) Venation of forewing not interrupted between marginal vein and submarginal vein (fig. 34); submarginal vein with more than two setae; females with smoky patch on wing beneath stigma (may be indistinct on small specimens); antennae of males with three long funicular branches . . . . Necremnus metalarus
Venation of forewing interrupted between marginal vein and submarginal vein; submarginal vein with only two setae (fig. 35); no smoky patch on wings of females; antennae of males unbranched. 24

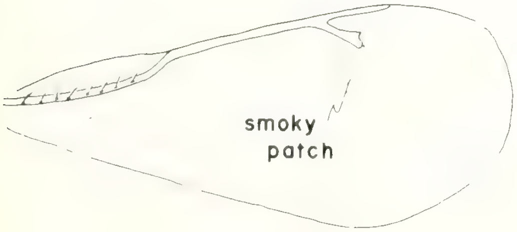

Figure 34.--Necremnus metalarus

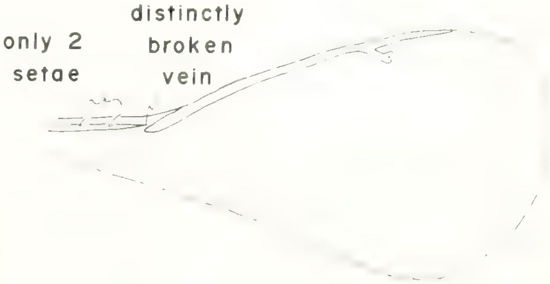

Figure 35.--Chrysocharis laricinellae

24. (23) Parapsidal grooves impressed for less than half the distance to the scutellum, represented posteriorly at most by a broad impression; anterior edge of scutellum between axillae straight; pronotal collar distinctly margined (fig. 36); specimens collected in June approximately 2 mm long, bright green body, white legs . . . . Chrysocharis laricinellae

Parapsidal grooves distinct for more than half the distance to the scutellum; anterior edge of scutellum between axillae curved; pronotal collar not distinctly margined (fig. 37); specimens collected in June approximately 1 mm long or less, bluish-green to purplish body color. . . . . Derostenus sp.

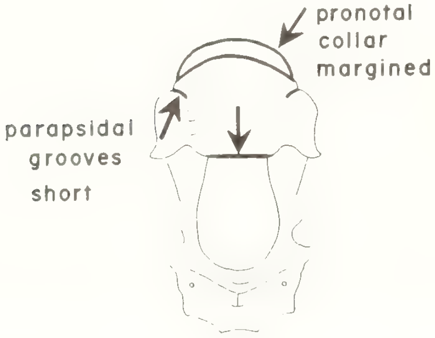

Figure 36.--Chrysocharis laricinellae

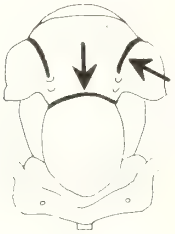

Figure 37.--Derostenus sp.

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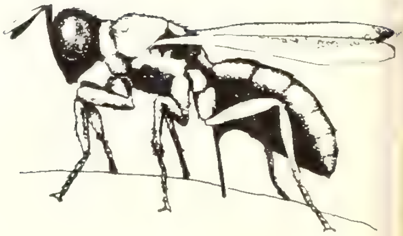
Acknowledgments

I am grateful to the following persons for determinations provided over the course of the past several years: B. D. Burks, R. W. Carlson, G. Gordh, E. E. Grissell, P. M. Marsh, and C. F. W. Muesebeck--either current or former members of Systematic Entomology Laboratory, Insect Identification and Beneficial Insect Introduction Institute--also C. M. Yoshimoto, Biosystematics Research Institute, Canada Agriculture. I appreciate helpful suggestions provided during reviews of the key and manuscript by D. Bridgewater, R. L. Johnsey, L. F. Pettinger, L. J. Theroux, and--especially--T. R. Torgersen.



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1979. Illustrated key to introduced and common native parasites of larch casebearer. USDA For. Serv. Res. Pap. PNW-262, 12 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

A key to introduced parasites of larch casebearer and commonly recovered native parasites features labeled and highlighted line drawings to facilitate identification.

KEYWORDS: Parasites (insect)(-forest pest control, larch casebearer, Coleophora laricella, keys (insect parasites).

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August 1979

Gross Yields for Even-Aged Stands of Douglas-fir and White or Grand Fir East of the Cascades in Oregon and Washington

P. H. Cochran

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ACKNOWLEDGMENT

The work leading to this publication was funded in part by the USDA Tussock Moth Expanded Research and Development Program.

METRIC EQUIVALENTS

1 inch = 2.54 centimeters
1 foot = 0.304 8 meter
1 acre = 0.404 7 hectare
1 square foot/acre =
0.229 6 square meter/hectare
1 cubic foot/acre =
0.069 97 cubic meter/hectare

CONTENTS

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GROSS YIELDS FOR EVEN-AGED STANDS OF DOUGLAS-FIR AND WHITE OR GRAND FIR EAST OF THE CASCADES IN OREGON AND WASHINGTON

REFERENCE ABSTRACT

Cochran, P. H.
1979. Gross yields for even-aged stands of Douglas-fir and white or grand fir east of the Cascades in Oregon and Washington. USDA For. Serv. Res. Pap. PNW-263, 17 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Equations and tables for predicting net and gross yields for Douglas-fir and white (grand) fir in even-aged stands east of the Cascade Range in Oregon and Washington are presented. Data were collected in stands where height growth apparently was never suppressed by competing understory vegetation, high density, or top damage once the heights of the dominants became greater than 4.5 feet.

KEYWORDS: Yield tables, yield table construction, increment (gross), increment (net), stem analysis, measurement systems, even-aged stands, Douglas-fir, *Pseudotsuga menziesii*, white fir, *Abies concolor*, grand fir, *Abies grandis*.

Research Summary

RESEARCH PAPER PNW-263

1979

Stem analyses of selected sample trees in temporary sample plots in even-aged stands were used to calculate gross periodic annual increments. Volume and basal area of the sample plots at the time of sampling were regarded as net volume and net basal area. Multiple regression methods were used to relate net basal area to site index and age at 4.5 feet. Then net volume and periodic annual increment were related to site index, age at 4.5 feet, and net basal area. Gross volume yield was obtained as a cumulative summary of gross volume increment from a breast-high age of 20 years plus the net volume at this age.

Introduction

Gross and net volume yield of Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) and white fir (*Abies concolor* (Gord. & Glend.) Lindl.) or grand fir (*Abies grandis* (Dougl.) Lindl.)[1] are given in total cubic feet of peeled volume for all stems 1.0-inch d.b.h. and larger. Gross yield represents all the bole wood produced and equals the net yield plus volume of the mortality. Thus, gross yield represents a potential value that intensive management can approach but never reach. Gross yield can be taken as an upper limit of yield in simulation models and as a guide that foresters can use to measure success of their own management practices.

Yields presented here are based on limited information. As more information becomes available, these yield tables should be revised. This information is presented now because no other yield information for these species in this geographical area is generally available. These yields are for even-aged stands where height growth has not been suppressed by overstory, competing understory vegetation, top damage, or high stand densities once the heights of the dominants in the stand become greater than 4.5 feet. This study was undertaken as part of the DFTM Expanded Research and Development Program to assess potential growth of healthy managed stands susceptible to tussock moth attack.

Methods

This study was conducted by sampling temporary plots. Sampling objectives were: (1) to obtain a good geographic representation of these stands as they occur on various habitat types and soils east of the Cascades in Oregon and Washington and (2) to sample 10 stands for each 10-year age span from breast-high ages of 0 to 120 years. These 10 stands (4 pure Douglas-fir, 4 pure white (grand) fir, and 2 mixed Douglas-fir-white (grand) fir) were to represent the widest possible range in site quality. As explained in the "Results" section, these objectives were not completely met.

Circular 1/5-acre sample plots (1/10-acre plots if height of dominants was 30 feet or less) had the following characteristics:

1. Stands on the plots were single storied and had no old remnant trees. They were even aged; that is, the ages of the youngest trees at ground line were at least 80 percent as old as the oldest trees.
2. The crown canopy was closed or nearly closed at the time of sampling, but there was no evidence of mortality within the last 10 years. For some plots there was no evidence of mortality exceeding 5 percent of the current plot volume for a period back in time longer than 10 years.
3. Each plot had a buffer strip at least equivalent in width to tree height. Isolated clumps of trees were not sampled.

D.b.h. was measured for all trees, and 1-inch diameter class distributions for each species found were constructed for each plot. From 12 to 16 trees of each species were cut. The three largest diameter trees of each species were sampled, and four to six additional trees of each species were picked randomly from diameter classes larger than the mean diameter. One tree was randomly picked from the class containing the mean diameter and four or five more trees of each species were randomly picked from diameter classes smaller than the mean diameter. This method of picking sample trees was used because the larger trees have faster rates of growth than do smaller trees, and I wanted to determine past growth rates for the plot. If the tallest tree on the plot was not picked in this sampling process, it was felled and used in determination of site index curves (Cochran 1979a, 1979b) but not in determination of volume growth rates. Site index (tables 1 and 2) is defined as the height of the tallest tree on the plot at a breast-high age of 50 years (Cochran 1979a, 1979b). For mixed white (grand) and Douglas-fir plots, site indexes were determined for both species, and the highest site index determined for the plot was used regardless of species.

---

[1] An *Abies grandis*-*A. concolor* species complex is recognized in the central Oregon Cascade Range. More southerly populations resemble *A. concolor*, whereas populations to the north become steadily more like *A. grandis* (Zobel 1973). In this study no attempt was made to separate white and grand fir trees from each other or their hybrids. Data were handled as if they were one species.

For plots that appeared to have little mortality in the past, a stem analysis was performed on each sample tree. Sample trees were sectioned at 1 foot, 4.5 feet, 10 feet, and then at 10-foot intervals up the stem unless dominant trees were shorter than 30 feet. For these younger stands, trees were sectioned a 5-foot intervals beyond 10 feet. Each section was measured so growth for successive 5-year periods back in time from the end of the 1975 growing season could be determined. Diameter measurements on each section were made on the longest and shortest radii through the center and averaged. Smalian's formula was used to determine volume of the bole segments above the stump for each period. The stump was considered a cylinder with the diameter determined at 1 foot. Tree volumes were the total of volumes of each segment, including the stump. Volume increment for any 5-year period was the difference in total volume at the start and end of the period.

Where there was evidence of mortality exceeding 5 percent of the current plot volume back in time beyond 10 years, only five of the sample trees (two large, two small, and one intermediate in size) were completely sectioned. For the remaining trees, heights at the end of 1975, 1970, 1965, and 1960 were determined by counting whorls and then cutting the stem and checking the age with a ring count. The 1-foot stump diameter outside bark was measured with a tape. Outside bark diameters at 10 feet and then at 5- or 10-foot intervals up the bole (depending on whether the height of the dominants was less or more than 30 feet) were measured with a caliper. Breast-high sections were removed and diameters determined for the end of 1975, 1970, 1965, and 1960. Equations were developed from trees sectioned at intervals relating bark thickness up the bole to bark thickness at breast height. These equations were used in the determination of inside bark volumes at the time of cutting for sample trees that were not sectioned. From the five trees sectioned at intervals on each plot, cylindrical form factors were determined for the time of sampling, and at the end of 1975, 1970, 1965, and 1960. Three separate linear regressions relating form factors in 1970, 1965, and 1960 to current form factors for the sectioned sample trees were calculated and used to determine form factors back in time for the nonsectioned sample trees. These estimated cylindrical form factors, along with the corresponding heights and diameters, were then used to calculate volumes for each nonsectioned sample tree at each desired point in time: Volume = (basal area) (total height)(form factor). Basal area at each point in time was determined from the diameter measurements;

Table 1--Values for a and by by years for the family of regressions[1] for estimating site index for Douglas-fir east of the Cascades in the Pacific Northwest

Breast-high age	Years between decades																			
	0		1		2		3		4		5		6		7		8		9	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Years																				
10	32.217	3.235	30.319	2.986	38.679	2.778	27.069	2.602	25.550	2.451	24.113	2.319	22.751	2.204	21.457	2.103	20.228	2.012	19.056	1.931
20	17.940	1.858	16.875	1.792	15.585	1.731	14.886	1.676	13.958	1.625	13.069	1.579	12.219	1.535	11.406	1.495	10.627	1.458	9.881	1.423
30	9.168	1.390	8.484	1.359	7.830	1.331	7.204	1.304	6.605	1.278	6.032	1.254	5.483	1.231	4.959	1.209	4.458	1.188	3.979	1.168
40	3.522	1.150	3.085	1.132	2.760	1.114	2.274	1.098	1.896	1.082	1.537	1.067	1.196	1.053	.872	1.039	.565	1.025	.274	1.012
50	0	1	-.260	.988	-.505	.976	-.735	.965	-.951	.954	-1.153	.944	-1.342	.934	-1.518	.924	-1.681	.914	-1.832	.905
60	-1.971	.896	-2.098	.887	-2.214	.879	-2.319	.870	-2.413	.862	-2.496	.854	-2.569	.847	-2.632	.839	-2.685	.832	-2.729	.825
70	-2.764	.818	-2.789	.811	-2.806	.804	-2.814	.798	-2.814	.791	-2.805	.785	-2.789	.779	-2.764	.773	-2.732	.767	-2.693	.761
80	-2.646	.756	-2.593	.750	-2.532	.745	-2.465	.740	-2.391	.734	-2.311	.729	-2.224	.724	-2.132	.719	-2.033	.714	-1.928	.709
90	-1.818	.705	-1.703	.700	-1.582	.695	-1.455	.691	-1.324	.687	-1.187	.682	-1.046	-.961	-.900	.674	-.749	.669	-.594	.665
100	-.434	.661																		

[1] To estimate site index, measure height of the 3 tallest trees per 1/5-acre plot. Determine breast-high age for each of these trees. Select appropriate a and b values above. Substitute values in the equation, Site index - 4.5 feet = a + b (height - 4.5 feet). For example, for a tree 53 years old at breast height and 60 feet in total height, solve the equation, SI - 4.5 = -0.735 + 0.965 (60 - 4.5), for a site index of 57.3. Determine the site index for each of the 3 trees. The highest site index determined is the site index for the 1/5-acre plot.

Source: Cochran (1979a).

Table 2--Values for a and b by years for the family of regressions[1] for estimating site index for white or grand fir east of the Cascades in the Pacific Northwest

Breast-high age	Years between decades																			
	0		1		2		3		4		5		6		7		8		9	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Years																				
10	53.778	2.353	52.315	2.177	50.808	2.035	49.266	1.917	47.699	1.819	46.112	1.735	44.511	1.663	42.903	1.600	41.290	1.546	39.678	1.497
20	38.069	1.455	36.467	1.416	34.876	1.382	33.296	1.350	31.732	1.322	30.185	1.296	28.656	1.273	27.149	1.251	25.663	1.231	24.201	1.212
30	22.764	1.195	21.353	1.179	19.968	1.164	18.612	1.150	17.283	1.137	15.983	1.125	14.711	1.113	13.470	1.102	12.257	1.092	11.075	1.082
40	9.922	1.073	8.799	1.064	7.706	1.056	6.641	1.048	5.607	1.040	4.601	1.033	3.624	1.026	2.675	1.019	1.754	1.012	.860	1.006
50	0	1.000	-.846	.994	-1.659	.989	-2.447	.983	-3.210	.978	-3.948	.973	-4.662	.968	-5.353	.963	-6.020	.958	-6.665	.954
60	-7.288	.949	-7.889	.945	-8.469	.941	-9.029	.936	-9.569	.932	-10.090	.928	-10.591	.924	-11.074	.920	-11.539	.917	-11.987	.913
70	-12.417	.909	-12.831	.906	-13.228	.902	-13.609	.899	-13.975	.895	-14.326	.892	-14.661	.888	-14.983	.885	-15.290	.882	-15.584	.878
80	-15.863	.875	-16.130	.872	-16.384	.869	-16.625	.866	-16.853	.863	-17.069	.859	-17.273	.856	-17.466	.853	-17.646	.850	-17.815	.847
90	-17.973	.844	-18.119	.842	-18.255	.839	-18.379	.836	-18.493	.833	-18.596	.830	-18.688	.827	-18.770	.824	-18.841	.823	-18.901	.819
100	-18.951	.816																		

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[1] To estimate site index, measure total height of up to 5 tallest trees per 1/5-acre plot; determine breast-high age for each. Select appropriate a and b values above. Substitute values in the equation, Site index - 4.5 feet = a + b (height - 4.5 feet). For example, for a tree 53 years old at breast height and 80 feet in total height, solve the equation, Site index - 4.5 feet = -2.447 feet + 0.983 (80 feet - 4.5 feet), for a site index of 76.3 feet. Determine the site index for each sample tree. The highest site index determined is the site index for white or grand fir on the 1/5-acre plot.

Source: Cochran (1979b).

a constant ratio was assumed for diameter outside bark and diameter inside bark.

Different procedures for sectioning were used on the two classes of plots because I wanted to project plots back in time as far as possible where mortality appeared to be negligible for another study. Where significant mortality appeared to have occurred beyond 10 or 20 years in the past, the second sectioning procedure, which was less time consuming, allowed accurate determinations of growth in the recent past. Sections at ground line were also taken on all plots from at least five trees, (two large, two small, and one intermediate) to determine total stand age and to make certain the stand was even aged.

Volume of sample trees on each plot at the time of cutting was related to their basal area by the equation:

$$\text{Log (initial volume)} = c + d \text{ (log current basal area).}$$

Basal area increment and volume increment of the sample trees for each period back in time on each plot was also related to their basal area at the time of cutting by the equation:

$$\text{Log (basal area increment)} = c_1 + d_1 \text{ (log current basal area),}$$

and

$$\text{log (volume increment)} = c_2 + d_2 \text{ (log current basal area).}$$

The coefficients of these three equations, determined separately for each plot, were then used to determine the initial volume of the uncut trees on the plot and the volume increment and basal area increment for these uncut trees for past time periods. Coefficients c_1, c_2, d_1, and d_2 varied, of course, on each plot with each time period. Volumes and increments for the cut trees were added to those calculated for the uncut trees (from the appropriate regressions) to obtain plot totals. Plot totals were converted to values per acre. By subtracting volume increments and basal area increments from initial volumes and basal areas, I projected all plots back to 1960. Plots where all the cut trees were sectioned were projected farther back in time to the point where the equations no longer were good predictors of increment.

Volume and basal area increments as a function of age were plotted for each plot. Age was determined by averaging the breast-high ages of the sample trees. Comparison of the shapes of the curves for plots projected 30 or more years back in time showed that certain periods broke above or below general trends for all plots. The 1915-20, 1930-35, 1950-55, and the 1965-70 periods were lower than the general trend for the majority of the plots scattered throughout eastern Oregon and Washington.[2] These periods were probably unusually dry. Eight plots showed marked and prolonged drops in increment, with later recovery. These plots must have been subject to severe attack by insects or to some other disaster. Even though these plots appeared healthy at the time of sampling, they were not used in determining yields reported here. The 1970-75 period seemed not to be one of climatic extremes, and crown canopy for the sample plots had completely or almost closed by this time. Therefore, we used increment for this period as the gross periodic annual increment.

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[2] In an investigation of past diameter growth of ponderosa pine in eastern Oregon and Washington, James W. Barrett, Research Forester, found pronounced dips in diameter growth in either or both 1917 and 1918, generally poor growing periods from 1924 to 1937 and 1948 to 1953, and a pronounced dip in 1968. Data on file at the Silviculture Laboratory, Bend, Oregon.

Multiple regression methods were used to relate the average plot volume increment for the 1970-75 period (the gross periodic annual volume increment) to the site index, the average breast-high age, and the basal area at the midpoint of this period. Volume and basal area found on the plots at the time of sampling were accepted as net yield and net basal area. Multiple regression methods were used to relate net volume to net basal area, site index, and breast-high age. Gross volume yield was obtained as a cumulative summary of gross periodic annual increment from a breast-high age of 20 years plus the net yield at breast-high age 20 (Dahms 1964, 1975; Curtis 1967).

Gross periodic annual basal area increments were also determined. Plot basal area increments for each species were divided by the plot basal area for that species at the midpoint of the period. These periodic basal area increments per unit of basal area were related to site index and age by multiple regression techniques. The resulting equations were then combined with the net basal area functions to determine gross periodic annual basal area increments. Determining gross basal increments in this way allowed use of two values for white (grand) fir for breast-high ages less than 25 years.

It should be noted that the subjective selection of small plots with complete or nearly complete crown closure but no evidence of recent mortality may produce net basal areas and volumes somewhat higher than are actually attainable on substantial areas. The ratio of net to gross increment may also be overestimated.

Results

A total of 97 plots were sampled; therefore, the sampling objectives were not completely met. Presence of older remnant trees, dense clumps of trees separated by openings, thinning, harvest cutting, and near absence of young stands with closed crown canopies caused difficulty in finding plots that met our criteria, particularly in stands less than 30 years and older than 100. After they were sampled, several plots were discarded from the study because abrupt breaks in the height growth curves for the sectioned sample trees showed severe damage in the past, and it was now impossible to assign a meaningful site index value to these plots. A few plots were discarded because their basal areas were very high and the shape of their height growth curves indicated that density was retarding height growth and there was no way to assign a site index value. Two plots were rejected because the ages at ground line were not within the limits we could accept as "even-aged."

Net basal area and volume.--Twenty six plots with greater than 90 percent basal area Douglas-fir and 26 additional plots with at least 90 percent basal area white (grand) fir were used to define the net basal area curves for each species. The site indexes for these plots within each 10-year breast-high age class were:

Breast-high age class	SITE INDEX (FEET) Douglas-fir	White or grand fir
11-20	104, 110.1, 117.8	--
21-30	59.4, 67.3, 87.7	--
31-40	--	79.3, 94.4, 94.6, 95.3, 96, 102.5
41-50	81, 84.9, 105	74, 90.4
51-60	79, 101.7	64.2, 71.9, 73.5, 83.5
60-70	79, 85, 87, 96.3, 102.4, 105.4	53.1, 65.9, 69.2, 90, 90, 98
71-80	52.7, 69.1, 73.5, 106.4	58.9, 59.6, 63.9, 89, 92.3
81-90	63.1, 65.2, 69, 69.2	74.8, 94.5
91-100	54.3	64.5

Net Douglas-fir basal area (table 3), BA, is:

$$BA = e^{(6.0735 + 7.4887/\log \text{age} + 0.22185 \log \text{SI} - 64.2213/(\log \text{SI} \cdot \log \text{age}))}.$$

The standard error and R^2 values are 33.0 ft^2/acre and 0.79.

Net white (grand) fir basal area (table 4), BA_1, is:

$$BA_1 = e^{(6.3216 + 0.1819 \log \text{SI} - 0.9365/\log \text{age} - 22.4376/(\log \text{SI} \cdot \log \text{age}))};$$

standard error is 27.7 ft^2/acre and R^2, 0.54.

In the two previous equations and in those that follow, SI is site index, age is breast-high age, logarithms are natural, and the standard errors and R^2 values are for the equations as written, not their logarithmic forms.

Thirty-one plots were used to describe the net volume equation for Douglas-fir and 37 plots for white (grand) fir. Some additional plots which were not quite as pure were used for each species along with those used for obtaining the basal area curves. The additional plots had from 15 to 30 percent basal area of other species besides the

Table 3--Net basal area of Douglas-fir east of the Cascades in Oregon and Washington as a function of age at breast height and site index[1]

Breast-high age	Site index (feet) 50	60	70	80	90	100	110
Years	- - - - - - - - -	- Square feet	per acre	- - - - - - - - -			
20	53	70	87	105	122	140	157
25	65	84	104	124	143	162	181
30	75	97	118	140	160	181	201
35	84	107	130	153	175	196	217
40	92	117	141	164	187	210	231
45	99	125	150	175	198	221	243
50	106	132	159	184	208	232	254
55	111	139	166	192	217	241	264
60	117	145	173	199	225	249	273
65	122	151	179	206	232	257	281
70	126	156	185	212	239	264	288
75	131	161	190	218	245	270	295
80	135	166	195	224	251	276	301
85	139	170	200	229	267	282	307
90	142	174	205	233	261	287	312
95	146	178	209	238	266	292	318
100	149	182	213	242	270	297	322

[1] Reference age for site index is 50 years at 4.5 feet.

Table 4--Net basal area of white (grand) fir east of the Cascades in Oregon and Washington as a function of age at breast height and site index[1]

Breast-high age	Site index (feet)						
	50	60	70	80	90	100	110
Years	Square feet per acre						
20	122	138	151	164	175	185	195
25	143	160	175	188	200	212	222
30	159	178	194	208	221	233	244
35	174	193	210	225	238	251	263
40	186	206	223	239	253	266	278
45	196	217	235	252	266	280	292
50	206	227	246	263	278	291	304
55	214	236	255	272	288	302	315
60	222	244	264	281	297	311	324
65	229	252	272	289	305	320	333
70	236	259	279	297	313	328	341
75	242	265	286	304	320	335	349
80	247	271	292	310	327	342	356
85	252	276	297	316	333	348	362
90	257	282	303	321	338	354	368
95	262	286	308	327	344	359	373
100	266	291	312	331	349	364	379

[1] Reference age for site index is 50 years at 4.5 feet.

one of interest. Additional species were usually mixtures of western larch (*Larix occidentalis* (Nutt.)), Engelmann spruce (*Picea engelmannii* (Parry)), ponderosa pine (*Pinus ponderosa* (Laws.)), western white pine (*Pinus monticola* (Dougl.)), and white or grand fir in the Douglas-fir plots and mixtures of very small amounts of larch and larger amounts of Engelmann spruce plus Douglas-fir in the white or grand fir plots. The additional plots furnished some high site indexes at ages 80 to 120 years for Douglas-fir and provided some additional data at ages below 60 years for both species.

The net volume for Douglas-fir (table 5), V, is:

$$V = e^{(1.507 + 0.4215 \log SI + 1.4052 \log BA - 64.8795/(\log age \cdot \log SI) + 138.8385/(\log age \cdot \log SI \cdot \log BA))}.$$

Standard error and R^2 values are 869.3 ft^3/acre and 0.97.

White or grand fir net volume (table 6), V_1, is:

$$V_1 = e^{(13.5218 - 33.5588/(\log SI \cdot \log BA_1) - 317.4388/(\log age \cdot \log SI \cdot \log BA_1}$$

standard error is 1,005.6 ft^3/acre and R^2, 0.90.

Gross periodic annual volume increments for Douglas-fir were determined from the same 26 plots used in finding the equation for net basal area plus one additional plot that contained 20 percent white (grand) fir. This plot was 125 years old at the time of sampling and had a site index of 97.4. More mixed plots were not used because the larch and pine in these Douglas-fir plots were growing at different rates than the Douglas-fir. In young stands, larch and pine will outgrow

Table 5--Net volume of Douglas-fir east of the Cascades in Oregon and Washington as a function of age at breast height and site index[1]

Breast-high age	Site index (feet)						
	50	60	70	80	90	100	110
Years	Cubic feet per acre						
20	481	717	1,014	1,371	1,787	2,262	2,793
25	669	1,010	1,433	1,937	2,518	3,175	3,905
30	865	1,311	1,860	2,507	3,248	4,081	5,001
35	1,064	1,614	2,284	3,070	3,965	4,964	6,063
40	1,263	1,914	2,701	3,619	4,660	5,817	7,085
45	1,460	2,208	3,109	4,153	5,332	6,639	8,065
50	1,654	2,496	3,505	4,670	5,981	7,428	9,004
55	1,844	2,778	3,890	5,170	6,606	8,187	9,904
60	2,030	3,051	4,264	5,654	7,208	8,916	10,767
65	2,213	3,318	4,626	6,121	7,790	9,618	11,596
70	2,391	3,578	4,978	6,574	8,350	10,294	12,392
75	2,565	3,830	5,319	7,011	8,892	10,945	13,158
80	2,735	4,076	5,650	7,436	9,415	11,573	13,897
85	2,901	4,316	5,972	7,847	9,922	12,180	14,609
90	3,064	4,550	6,285	8,245	10,412	12,767	15,296
95	3,222	4,777	6,589	8,633	10,888	13,336	15,961
100	3,378	5,000	6,885	9,009	11,349	13,886	16,605

[1] Reference age for site index is 50 years at 4.5 feet.

Table 6--Net volume of white (grand) fir east of the Cascades in Oregon and Washington as a function of age at breast height and site index[1]

Breast-high age	Site index (feet)						
	50	60	70	80	90	100	110
Years	Cubic feet per acre						
20	446	736	1,073	1,444	1,838	2,249	2,671
25	821	1,284	1,800	2,350	2,921	3,504	4,093
30	1,244	1,879	2,567	3,285	4,018	4,757	5,495
35	1,689	2,489	3,337	4,209	5,089	5,968	6,839
40	2,142	3,095	4,091	5,104	6,118	7,122	8,111
45	2,593	3,690	4,823	5,964	7,098	8,216	9,310
50	3,036	4,268	5,527	6,787	8,031	9,250	10,440
55	3,470	4,827	6,203	7,571	8,916	10,228	11,505
60	3,892	5,366	6,851	8,320	9,757	11,155	12,511
65	4,302	5,886	7,473	9,034	10,556	12,033	13,462
70	4,699	6,387	8,068	9,716	11,318	12,867	14,363
75	5,084	6,870	8,640	10,368	12,044	13,661	15,219
80	5,458	7,335	9,188	10,993	12,737	14,417	16,033
85	5,819	7,784	9,716	11,591	13,400	15,139	16,810
90	6,170	8,217	10,223	12,166	14,035	15,830	17,551
95	6,509	8,635	10,712	12,718	14,645	16,492	18,260
100	6,839	9,039	11,183	13,249	15,230	17,126	18,940

[1] Reference age for site index is 50 years at 4.5 feet.

Douglas-fir; but at ages beyond 50 or 60 years, Douglas-fir outgrows the larch and pine. The same 37 plots used in determining the net volume equations for white (grand) fir were also used in determining gross periodic annual increments. The mixed plots within these samples contained mostly Douglas-fir and small amounts of Engelmann spruce in addition to the white (grand) fir. Annual gross volume growth per unit basal area[3] for these species on these plots was not significantly different from annual gross volume growth per unit basal area for white fir.

Gross periodic annual volume increment (fig. 1), dV, for Douglas-fir is:

$$\begin{aligned} dV = e^{(-8.2577} &+ 1.7487 \log SI \\ &+ 1.3292 \log BA \\ &+ 0.1699 \log age \cdot \log SI \\ &- 0.0484 \log age \cdot \log SI \cdot \log BA) \end{aligned}$$

Standard error and R^2 values are 21.1 ft^3/acre per year and 0.92.

Gross periodic annual volume increment for white or grand fir (fig. 2), dV_1, is:

$$\begin{aligned} dV_1 = e^{(0.7391} &+ 0.3847 \log BA_1 \\ &+ 0.2044 \log SI \cdot \log BA_1 \\ &- 0.02541 \log age \cdot \log SI \cdot \log BA_1) . \end{aligned}$$

Standard error and R^2 values are 25.3 ft^3/acre per year and 0.80.

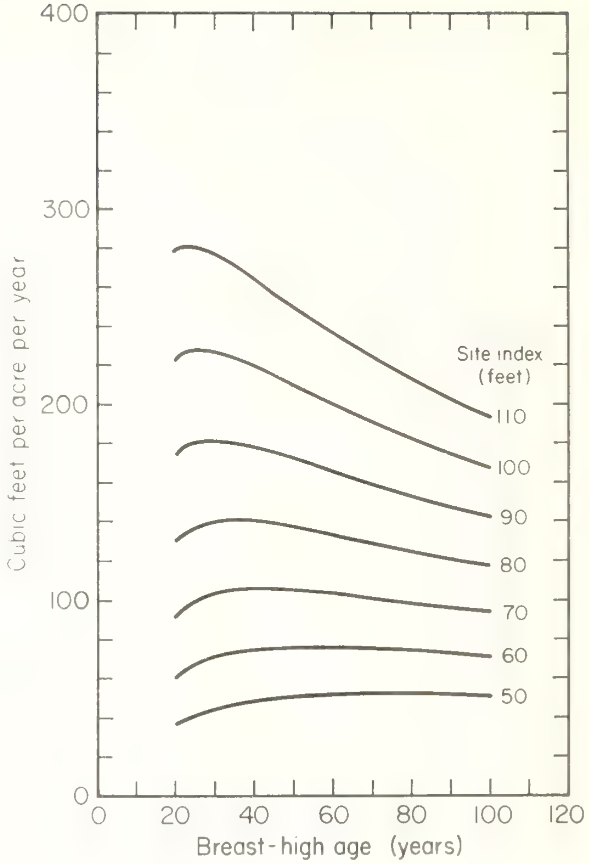

Figure 1.--Gross periodic annual volume increment for Douglas-fir east of the Cascades in Oregon and Washington.

The gross volume yields determined from these increment equations and the net yields at breast-high age 20 years are given in tables 7 and 8.

Gross periodic annual basal area increments per unit basal area were determined from 43 plots for Douglas-fir and 46 plots for white (grand) fir. These plots include those used in determining the gross periodic annual volume increments plus additional plots where at least 40 percent of the basal area was of the species concerned. For Douglas-fir gross periodic annual basal area increment per unit of basal area is:

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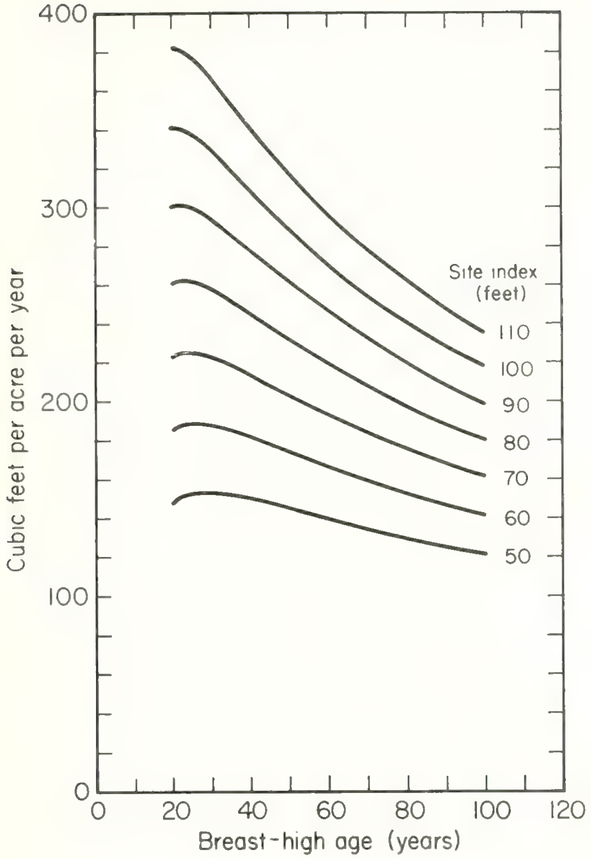
[3] Annual gross volume growth per unit basal area here is the average volume growth for a given species on a plot during the 1970-75 period divided by the midpoint basal area of the period for that species.



$$d(BA)/BA = e^{(10.0227 - 0.5686 \log SI - 2.7624 \log age - 28.4193/(\log SI \cdot \log age) + 0.00668 (\log age)^3 \cdot \log SI - 0.01102 (\log SI)^2 \cdot \log age)}$$

Standard error and R^2 values are 0.0068 and 0.92.

For white (grand) fir,

$$d(BA_1)/BA_1 = e^{(1.4743 - 1.5379 \log age + 0.5212 \log age/\log SI + 0.00000001 (\log age)^{10} \cdot \log SI)}$$

Figure 2.--Gross periodic annual volume increment for white (grand) fir east of the Cascades in Oregon and Washington.

Table 7--Gross volume yield for Douglas-fir east of the Cascades in Oregon and Washington[1]

Breast-high age	Site index						
	50	60	70	80	90	100	110
Years	- - - - - - - - - - - Cubic feet per acre - - - - - - - - - -						
25	679	1,042	1,497	2,042	2,675	3,393	4,193
30	897	1,390	2,004	2,736	3,579	4,530	5,585
35	1,128	1,753	2,525	3,437	4,483	5,656	6,951
40	1,369	2,125	3,051	4,138	5,378	6,762	8,283
45	1,616	2,501	3,578	4,835	6,261	7,846	9,580
50	1,868	2,881	4,105	5,525	7,129	8,904	10,841
55	2,123	3,261	4,628	6,206	7,980	9,938	12,066
60	2,380	3,641	5,146	6,877	8,816	10,947	13,257
65	2,638	4,019	5,660	7,538	9,634	11,932	14,417
70	2,897	4,396	6,168	8,189	10,437	12,895	15,545
75	3,156	4,770	6,670	8,829	11,224	13,835	16,645
80	3,414	5,142	7,167	9,460	11,996	14,755	17,717
85	3,672	5,511	7,657	10,080	12,754	15,654	18,763
90	3,930	5,877	8,142	10,691	13,497	16,535	19,785
95	4,186	6,240	8,620	11,293	14,227	17,397	20,783
100	4,442	6,599	9,093	11,885	14,944	18,242	21,759

[1] Reference age for site index is 50 years at 4.5 feet.

Table 8--Gross volume yield for white (grand) fir east of the Cascades in Oregon and Washington[1]

Breast-high age	Site index (feet)						
	50	60	70	80	90	100	110
Years	Cubic feet per acre						
25	1,202	1,673	2,195	2,754	3,340	3,947	4,567
30	1,967	2,613	3,312	4,052	4,821	5,613	6,420
35	2,730	3,543	4,413	5,323	6,266	7,231	8,214
40	3,484	4,458	5,489	6,563	7,668	8,797	9,945
45	4,227	5,355	6,540	7,768	9,028	10,312	11,614
50	4,957	6,233	7,565	8,939	10,345	11,775	13,223
55	5,674	7,092	8,564	10,078	11,623	13,191	14,777
60	6,378	7,931	9,538	11,185	12,862	14,562	16,278
65	7,069	8,752	10,487	12,261	14,065	15,890	17,731
70	7,746	9,555	11,414	13,310	15,234	17,178	19,137
75	8,412	10,342	12,319	14,332	16,371	18,429	20,502
80	9,065	11,111	13,203	15,328	17,478	19,646	21,826
85	9,706	11,866	14,068	16,301	18,557	20,830	23,113
90	10,337	12,605	14,914	17,251	19,610	21,983	24,366
95	10,956	13,331	15,742	18,180	20,637	23,107	25,586
100	11,566	14,043	16,554	19,089	21,641	24,204	26,775

[1] Reference age for site index is 50 years at 4.5 feet.

Standard error and R^2 values are 0.004 and 0.96. Multiplying these functions by the appropriate expression for net basal area produces the gross periodic annual basal area increments (table 9 and 10).

Table 9--Gross periodic annual basal area increment for Douglas-fir east of the Cascades in Oregon and Washington as a function of age at breast height and site index[1]

Breast-high age	Site index (feet)						
	50	60	70	80	90	100	110
Years	Square feet per acre per year						
15	3.8	5.2	6.6	7.9	9.1	10.3	11.4
20	3.5	4.6	5.7	6.7	7.6	8.5	9.3
25	3.1	4.1	4.9	5.7	6.4	7.1	7.7
30	2.8	3.6	4.3	4.9	5.5	6.1	6.6
35	2.6	3.2	3.8	4.4	4.9	5.4	5.8
40	2.3	2.9	3.5	4.0	4.4	4.8	5.2
45	2.2	2.7	3.2	3.6	4.0	4.4	4.7
50	2.0	2.5	2.9	3.3	3.7	4.0	4.3
55	1.9	2.3	2.7	3.1	3.4	3.8	4.0
60	1.8	2.2	2.6	2.9	3.2	3.5	3.8
65	1.7	2.1	2.5	2.8	3.1	3.3	3.6
70	1.6	2.0	2.3	2.6	2.9	3.2	3.4
75	1.5	1.9	2.2	2.5	2.8	3.0	3.3
80	1.5	1.8	2.2	2.4	2.7	2.9	3.2
85	1.4	1.8	2.1	2.4	2.6	2.8	3.1
90	1.4	1.7	2.0	2.3	2.5	2.8	3.0
95	1.4	1.7	2.0	2.2	2.5	2.7	2.9
100	1.3	1.6	1.9	2.2	2.4	2.6	2.8

[1] Reference age for site index is 50 years at 4.5 feet.

Table 10--Gross periodic annual basal area increment for white (grand) fir east of the Cascades in Oregon and Washington as a function of age at breast height and site index[1]

Breast-high age	Site index (feet)						
	50	60	70	80	90	100	110
Years	Square feet per acre per year						
15	9.4	10.5	11.5	12.4	13.2	13.9	14.6
20	8.0	8.8	9.5	10.2	10.8	11.3	11.9
25	6.8	7.5	8.1	8.6	9.0	9.5	9.9
30	5.9	6.5	6.9	7.4	7.7	8.1	8.4
35	5.2	5.7	6.1	6.4	6.7	7.0	7.3
40	4.6	5.0	5.4	5.7	6.0	6.2	6.4
45	4.2	4.5	4.8	5.1	5.3	5.5	5.7
50	3.8	4.1	4.4	4.6	4.8	5.0	5.2
55	3.5	3.8	4.0	4.2	4.4	4.6	4.7
60	3.2	3.5	3.7	3.9	4.1	4.2	4.4
65	3.0	3.3	3.5	3.6	3.8	3.9	4.1
70	2.8	3.1	3.2	3.4	3.5	3.7	3.8
75	2.7	2.9	3.0	3.2	3.3	3.5	3.6
80	2.5	2.7	2.9	3.0	3.2	3.3	3.4
85	2.4	2.6	2.7	2.9	3.0	3.1	3.2
90	2.3	2.5	2.6	2.7	2.9	3.0	3.1
95	2.2	2.4	2.5	2.6	2.7	2.8	2.9
100	2.1	2.3	2.4	2.5	2.6	2.7	2.8

[1] Reference age for site index is 50 years at 4.5 feet.

Reasonableness of Results

NET BASAL AREA

The net basal area equations did a poorer job accounting for variability than did the equations for net volume or periodic annual increment. Net volume and periodic annual increment are a function of basal area as well as site index and age. Therefore, the net basal area functions must be good predictors if the net volume and periodic annual increment functions are to be reliable.

Douglas-fir.--Comparison of the basal area curves given here with preliminary results for the west side from a yield study of Douglas-fir by the Pacific Northwest Forest and Range Experiment Station and Weyerhaeuser Company show close to the same results for site indexes 75 to 90 feet.[4] For site index 110 feet, my curves are 15 percent higher for breast-high ages of 20 to 100.[5]

White (grand) fir.--The low R^2 value for my white fir basal area curves reflects high variability of the data, not the unreasonableness of shape. These white fir curves are generally shaped like my Douglas-fir curves and the curves for second-growth mixed conifer stands in California (Dunning and Reineke 1933).

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[4] The west-side index curves have a reference age of 50 years at breast height, but the heights are the average of a fixed number of largest diameter trees per acre. Therefore, they are not strictly comparable to my curves (table 1).

[5] Personal communication with Robert O. Curtis, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, Olympia, Washington.

As a partial check on the accuracy of the white fir basal area curves, a technician prism-cruised seven small, even-aged stands of white fir picked from aerial photos on the Deschutes National Forest in central Oregon. A 10.255 factor prism was used. Plots were systematically located on a 140-foot grid. The two tallest trees counted at each prism point were bored at breast height, and their heights were measured with a clinometer. Site index for the prism point was the highest of the determinations of the two trees. Basal areas and site indexes were averaged for all the points in each stand. The highest deviation between the average basal area and predicted values was 12 ft^2/acre (table 11).

GROSS VOLUME YIELD

Reliability of gross volume yields can be checked by comparing them with net yields (table 12). For Douglas-fir at age 80, net volume yield ranges from 80 percent of gross volume yield for site index 50 to 78.4 percent of the gross yield for site index 110. At age 100, the net volume yield is 76 percent of gross yeild for all site indexes; and if the yields are projected to 120 years, net yield ranges from 72.7 percent of gross for site index 50 to 74 percent for site index 110. This compares closely with results of Curtis (1967) and Staebler (1955). Staebler (1955) found that net volume yields for site III, west-side Douglas-fir represented 79 to 73 percent of gross volume yield at ages 80 to 120 years. Similarly, net volume yield of ponderosa pine represents 79 to 74 percent of gross yeild at ages 80 to 120 years for site index 80 (Meyer 1938). Net volume yield from the British Columbia yield table (British Columbia Forest Service 1947) for lodgepole pine represents 68 to 63 percent of gross volume yield at ages of 80 to 120 years. Dahms (1975) found that net volume yield

Table 11--Comparison of actual and predicted basal area values for 9 small, undamaged, even-aged white (grand) fir stands

Location	Approximate size	Number of plots	Age	Site index		Basal area		
				Range	Average	Range	Average	Predicted
	Acres		Years	Feet		Square feet per acre		
T. 19 S., R. 10 E., SE¼ sec. 6	30	19	79	54-73	62	133-420	262	274
T. 19 S., R. 10 E., NW¼ sec. 2	20	15	46	50-73	60	123-313	225	219
T. 19 S., R. 10 E., S½ sec. 20	10	10	93	56-80	67	205-405	302	300
T. 20 S., R. 7 E., SE¼ sec. 13	4	6	101	67-79	72	205-338	314	317
T. 14 S., R. 10 E., NE¼ sec. 10	5	6	70	79-99	90	297-359	309	313
T. 20 S., R. 7 E., NE¼ sec. 24	12	10	96	65-78	71	227-338	308	311
T. 19 S., R. 10 E., SW¼ sec. 6	20	15	85	64-83	73	246-395	315	303

Table 12--Net volume yield of white (grand) fir and Douglas-fir expressed as a percent of gross volume yield[1]

Breast-high age	Site index (feet)						
	50	60	70	80	90	100	110
Years	Percent						
	WHITE (GRAND) FIR						
80	60.2	66.0	69.6	71.7	72.9	73.4	73.5
85	60.0	65.6	69.1	71.1	72.2	72.7	72.7
90	59.7	65.2	68.5	70.5	71.6	72.0	72.0
95	59.4	64.8	68.0	70.0	71.0	71.4	71.4
100	59.1	64.4	67.6	69.4	70.4	70.8	70.7
	DOUGLAS-FIR						
80	80.1	79.3	78.8	78.6	78.5	78.4	78.4
85	79.0	78.3	78.0	77.8	77.8	77.8	77.9
90	78.0	77.4	77.2	77.1	77.1	77.2	77.3
95	77.0	76.6	76.4	76.4	76.5	76.7	76.8
100	76.0	75.8	75.7	75.8	75.9	76.1	76.3

[1] Reference age for site index is 50 years at 4.5 feet.

represented 63 to 73 percent of gross yield at age 120 years for site indexes ranging from 60 to 110.

Net volume yields for white (grand) fir are a smaller percentage of the gross volume yield than for Douglas-fir. At age 80, net yield ranged from 60 percent of gross yield for site index 50 to 73.7 percent for site index 110. At age 100, the percentages ranged from 59 for site index 50 to 71 for site index 110. If yields for white (grand) fir are projected to 120 years, net volume yields range from 58 to 68 percent of the gross volume yield for site index 50 to 110. These percentages are less certain than those for Douglas-fir because no white (grand) fir plots were sampled in the 20- to 30-year age class, and the starting point for accumulating gross yield was 20-year-breast-high age.

GROSS PERIODIC ANNUAL BASAL AREA GROWTH

Curtis (1967) presents gross periodic annual basal area growth of west-side Douglas-fir for site indexes of 80 to 140 feet (see footnote 4). For breast-high ages beyond 25 years, my curves are 0.3 to 0.4 ft^2/acre per year lower at site index 80 feet and 0.1 to 0.2 ft^2/acre per year higher at site index 110 feet. Under 15-year-breast-high age, the values presented by Curtis are higher than shown by my curves, but I had only one plot below this age.

I could locate no published values for gross basal area growth of white fir. The gross periodic annual basal area growth curves for white (grand) fir are higher than those for Douglas-fir as expected, except for site index 110 feet beyond the 95-year-breast-high age. No data were used in the construction of the white fir curves at these high sites and ages, however, and no data were used from plots below 20 years of age. Therefore, these curves above 80 years and for high sites and below 20 years are questionable.

Application

These results provide first approximations of potential production in pure or nearly pure, even-aged stands which are relatively uniform and in which no stagnation or serious injury occurs. Currently, many young stands do undergo periods when height growth is suppressed because of scattered remnant overstory trees, competing vegetation, and high densities. Perhaps these factors can be controlled by management practices in the future, but they make application of these results uncertain in many existing stands. Future management practices may moderate but not eliminate injuries to stands by insects, diseases, and storms. These results can be helpful in assessing the loss of productivity caused by injury. These results can be used to estimate potential production in existing pure or nearly pure stands where:

1. The stand is one storied, there are no older remnants from earlier stands, and the stand can be classified as even aged.
2. There are no visible signs of insect or disease attack that would reduce growth.
3. There are no narrow ring groups of 5 or more years which indicate suppression.
4. There are no remnants of excessive understory vegetation or suppression mortality that indicate severe competition early in the life of the stand.
5. The crown canopy is closed or very nearly closed.

For sampling applicable stands, site index should be determine by boring and measuring the heights of three to five of the tallest trees on a number of 1/5-acre plots. The highest site index value determined from these three to five trees is the site index for the plot. The average site index for all the plots sampled is the site index for the area of concern. Several more trees in the intermediate and codominant height classes should be bored on each plot, and the average age of all the bored trees should be used as the breast-high age. The average site index and breast-high age should then be used with the existing measured basal area in the appropriate equations to determine potential volume and basal area growth.

For applicable stands that are mixtures of white (grand) and Douglas-fir, site index should be determined for both species on each plot if both species have dominant trees. The highest site index determined should be recorded for the plot regardless of species. For stands that have 80 percent or more of their basal area in a single species, the stands can be considered as either Douglas-fir or white (grand) fir in the application of the equations and volume growth. For mixed stands of Douglas-fir and white (grand) fir that have more than 20 percent of their basal area in the minority species, I suggest solving the Douglas-fir and white (grand) fir equations separately with the existing basal areas and then adding the results together to determine growth rates.

The plots in this study did not include nonproductive areas, such as roads, streams, rock outcrops, and talus slopes. Therefore, land managers must make adjustments downward in applying these results to large areas. There is no simple way to make this adjustment. Bruce (1977) suggests that the areas of application "be surveyed with mappable nonproductive areas excluded, and an allowance determined for areas too small to map."

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Experiment Station
P.O. Box 3141
Portland, Oregon 97208

Cochran, P. H.
1979. Gross yields for even-aged stands of Douglas-fir and white or grand fir east of the Cascades in Oregon and Washington. USDA For. Serv. Res. Pap. PNW-263, 17 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Equations and tables for predicting net and gross yields for Douglas-fir and white (grand) fir in even-aged stands east of the Cascade Range in Oregon and Washington are presented. Data were collected in stands where height growth apparently was never suppressed by competing understory vegetation, high density, or top damage once the heights of the dominants became greater than 4.5 feet.

KEYWORDS: Yield tables, yield table construction, increment (gross), increment (net), stem analysis, measurement systems, even-aged stands, Douglas-fir, *Pseudotsuga menziesii*, white fir, *Abies concolor*, grand fir, *Abies grandis*.

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September 1979

Regeneration in Mixed Conifer Shelterwood Cuttings in the Cascade Range of Eastern Oregon

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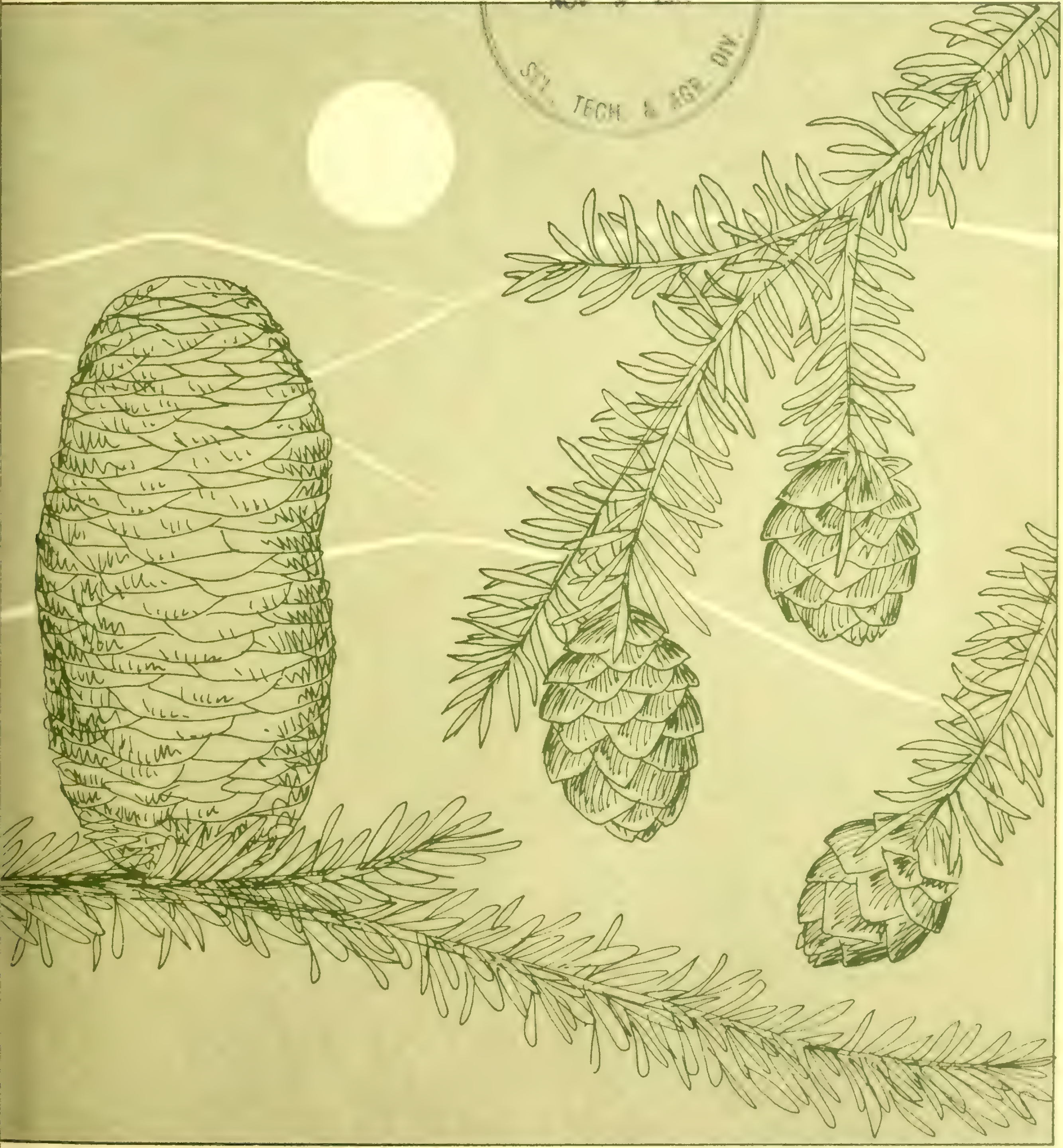

METRIC EQUIVALENTS

1 acre = 0.405 hectare
1 foot = 0.3048 meter
1 inch = 2.54 centimeters
1 mile = 1.61 kilometers
1 square foot = 0.0929 square meter
1 square foot/acre = 0.2296 square meter/hectare
1 tree/acre = 2.47 trees/hectare

Regeneration in mixed conifer shelterwood cuttings in the Cascade Range of eastern Oregon

Reference Abstract

Seidel, K. W.
1979. Regeneration in mixed conifer shelterwood cuttings in the Cascade Range of eastern Oregon. USDA For. Serv. Res. Pap. PNW-264, 29 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

A survey of shelterwood cuttings in mixed conifer forests in the eastern Oregon Cascade Range showed that, on the average, shelterwood units were well stocked with a mixture of advance, natural subsequent, and planted reproduction of a number of species. Because of slow invasion by understory vegetation, frequent heavy seed crops, and adequate density of the overstory, natural regeneration was prolific on most units. Planting is recommended only as a supplemental reforestation method. Greater stocking was associated with increasing overstory density and more exposed mineral soil; such factors as aspect, slope, and elevation had a positive or negative relationship to stocking depending on the species and plant community.

KEYWORDS: Regeneration (stand), regeneration (natural), regeneration (artificial), mixed stands, Oregon (Cascade Range), shelterwood cutting method.

RESEARCH SUMMARY
Research Paper PNW-264
1979

Regeneration of shelterwood cuttings in upper slope, mixed conifer forests in the eastern Oregon Cascade Range was surveyed for an overview of the status of reforestation and to identify key environmental factors influencing establishment of seedlings. Plots were randomly located in shelterwood units harvested during the 1970-73 period in the mountain hemlock/grouse huckleberry and mixed conifer/snowbrush-chinkapin plant communities in the Cascade Range.

On the average, shelterwood units were well stocked with a mixture of advance, natural subsequent, and planted reproduction of a number of species. An average of 63 percent of milacre quadrats were stocked in both plant communities, and density of seedlings of all origins averaged 4,483 per acre in the hemlock type

and 2,968 in the mixed conifer. Over 90 percent of the seedlings in both types were of natural postharvest origin. Although planted seedlings were only a small fraction of the total number of seedlings, the percentage of milacres stocked with planted trees was relatively high because of their good distribution over the plots. Planted seedlings were also dominant on more of the quadrats than their small numbers might suggest because of their greater height.

Greater stocking was generally associated with increasing density of the overstory and more exposed mineral soil. Other factors, such as aspect, slope, elevation, and understory vegetation, had a positive or negative effect on stocking, depending on the species and community. Equations for predicting stocking were derived for several species in both communities, but, because of the large amount of unexplained variation, they serve only as crude estimates of possible stocking.

Density of the residual overstory after the seed cut in a shelterwood method should be no greater than needed to obtain natural regeneration, so that established reproduction is not damaged or destroyed to an unacceptable degree when the overstory is removed. A range from 60 to 80 square feet of basal area per acre is recommended as the minimum level for establishing adequate natural regeneration in most shelterwood units in hemlock and mixed conifer communities. Logging and slash disposal operations in these shelterwood units broke up heavy, compact layers of litter and duff and exposed sufficient mineral soil for establishment of seedlings.

Only small amounts of understory vegetation were present in these shelterwood units. The slow invasion of understory vegetation, plus heavy seed crops every 3 or 4 years, and the uniform distribution of seed trees in shelterwood units resulted in an abundance of natural regeneration in most units. It appears that planting shelterwood units immediately after the seed cut is necessary only in the following cases: (1) in mixed conifer communities if residual basal area is reduced below 60 square feet per acre and (2) in pure mountain hemlock communities containing no other species in the overstory.

Blowdown of the residual overstory was greater in the mountain hemlock plots. The risk of blowdown can be reduced by marking leave trees which are fully crowned dominants or codominants (the most windfirm and also the best producers of seed) and by discriminating against mountain hemlock.

Removal of the residual overstory after the regeneration is established without unacceptable loss or damage to the reproduction is essential if the shelterwood method is to be successful. The key to achieving this goal is good coordination between timber and fuels management staffs and skillful application of logging techniques designed to preserve established regeneration.

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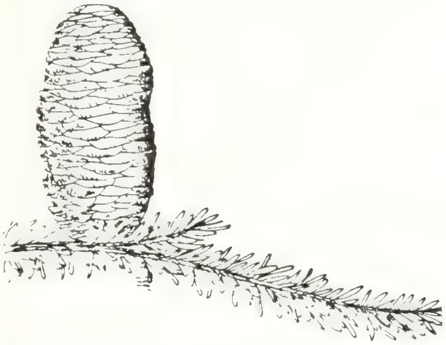

INTRODUCTION

During the late 1960's and 1970's, the shelterwood method has been used increasingly to harvest timber from upper slope mixed conifer forests of the east side Oregon Cascade Range. In some areas, this method has been tried as a means of modifying the harsh microclimatic conditions found on many high elevation clearcuts that cause difficulties in regeneration. And, as esthetic considerations became increasingly important, the shelterwood method was used in many areas open to public view to maintain the visual quality of the landscape.

Some of these shelterwood units are now old enough for regeneration to be established. Therefore, in 1978, I began a study to survey regeneration, the factors affecting its establishment, and the condition of the residual overstory. This paper reports the results of that field survey in 1978 on the Deschutes and Winema National Forests.

OBJECTIVES

The purpose of this study was to: (1) quantitatively evaluate the regeneration found on the shelterwood units, (2) evaluate condition of the residual overstories during the regeneration period, and (3) attempt to identify environmental factors associated with the presence or absence of regeneration.

Specific objectives were to:

1. Estimate success of regeneration in terms of stocking percentage and density (number per acre);
2. Estimate species composition of the regeneration;
3. Estimate stocking of regeneration of preharvest (advance) and postharvest (natural and planted) origin;
4. Estimate the relationship between regeneration and some measurable environmental variables, such as elevation, aspect, slope, and overstory density; and
5. Estimate survival and condition of the residual overstories.

STUDY AREAS

Study areas (plots) were located in the mixed conifer forest type of the eastern Cascade Range in the Deschutes and Winema National Forests (fig. 1). A number of plant communities have been identified within this type by Volland (1976). Identification of these plant communities is based on the dominant overstory tree and the dominant understory shrub, forb, or grass. Plots were located in two of these communities: (1) a high elevation mountain hemlock/grouse huckleberry community and (2) a lower elevation mixed conifer/snowbrush-chinkapin community. The major tree species found in these communities are ponderosa pine (*Pinus ponderosa* Laws.), lodgepole pine (*Pinus contorta* Dougl.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), grand fir (*Abies grandis* (Dougl.) Lindl.) white fir (*A. concolor* (Gord. & Glend.) Lindl.), Shasta red fir (*A. magnifica* var. shastensis Lemm.), western white pine (*Pinus monticola* Dougl.), and mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.). Understory vegetation in the mountain hemlock/grouse huckleberry community is generally sparse, consisting primarily of grouse huckleberry (*Vaccinium scoparium*), prince's pine (*Chimaphila umbellata*), and pine-mat manzanita (*Arctostaphylos nevadensis*). Major understory vegetation in the mixed-conifer/snowbrush-chinkapin community consists of snowbrush (*Ceanothus velutinus*), golden chinkapin (*Castanopsis chrysophylla*), pine-mat manzanita, and dogbane (*Apocynum pumilum*).

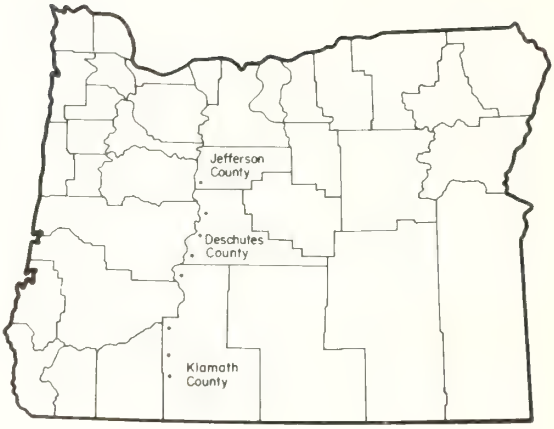

Figure 1.--Location of study areas in Oregon; eight to ten 10-acre plots were sampled in the vicinity of each dot.

Some characteristics of the shelterwoods sampled are given in table 1. In the mountain hemlock community, the number of trees per acre in the residual overstory ranged from 11 to 34, of which 51 percent were mountain hemlock, 35 percent red fir, 6 percent grand fir, 5 percent white pine, plus small numbers of Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), lodgepole pine, and Douglas-fir. In the mixed conifer type, from 6 to 46 trees per acre remained in the overstory; the three dominant species were grand fir (52 percent), Douglas-fir (23 percent), and red fir (17 percent). Ponderosa pine made up about 5 percent of the overstory; a few lodgepole pine, white pine, and Engelmann spruce were also

Table 1--Mean and range of some characteristics of shelterwood units sampled in 2 plant communities in the Cascade Range of eastern Oregon

Characteristic	Mountain hemlock/ grouse huckleberry		Mixed conifer/ snowbrush-chinkapin	
	Mean	Range	Mean	Range
Number of plots	30	--	45	--
Elevation (feet)	5718	5,200-6,400	5,111	4,150-5,800
Slope (percent)	5.0	0-25	3.4	0-19
Age (years)	7.0	5-8	6.1	5-8
		Residual overstory		
Number of trees per acre	20.0	11-34	19.0	6-46
Average diameter (inches)	25.4	15.3-37.2	26.5	18.1-38.2
Basal area (ft^2)	65.7	20-186	68.0	16-183
Crown closure (percent)	30.1	15-53	32.1	8-75
		Seed bed (percent coverage)[1/]		
Mineral soil	16.3	0-37	22.0	4-43
Litter	31.1	6-66	30.7	12-57
Slash	15.6	7-24	12.2	6-30
Litter and slash	34.7	14-74	30.2	11-60
		Understory vegetation (percent coverage)		
Forbs	0.8	0-9	9.2	0-38
Shrubs	2.5	0-12	9.5	0-36
Grasses and sedges	3.6	0-20	9.0	0-34

[1/] Total of all seed bed categories do not add to 100 percent because areas of some milacre subplots are occupied by rocks and stumps.

present (fig. 2). Slash in 69 shelterwood units was piled by machine and burned after the seed cut, and in 6 units it was not treated.

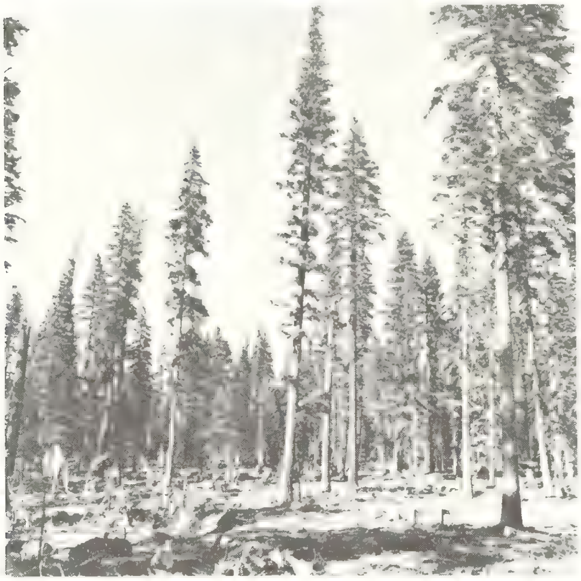

Figure 2.--This shelterwood unit in the mixed conifer community contains an average of 16 trees and 50 square feet of basal area per acre.

Plots were within the pumice plateau region of south-central Oregon. Soils in this region are immature Regosols (Vitrandepts), developed from aerially deposited dacite and rhyolitic pumice ejected from Mount Mazama (Crater Lake) about 6,500 years ago. These well-drained, coarse-textured soils have thin A horizons, low in fertility, which grade into unweathered sand and gravel. A finer textured buried soil is found at a depth of 2 to 6 feet (Larsen 1976).

METHODS

Survey Design and Plot Selection

The mountain hemlock and mixed conifer plant communities were considered separate populations. A record of shelterwood units harvested in 1973 or earlier in the two communities was obtained from the USDA Forest Service Regional Office in Portland, Oregon. Only units at least 5 years old were considered suitable for sampling so that reproduction would have had time to become established. The sampling unit was a square plot 10 acres in size. Therefore, all shelterwood areas 10 acres or larger and at least 5 years old were considered candidates for sampling. The total number of 10-acre plots in each plant community was then determined; fractional portions of 10-acre areas were ignored. In the mixed conifer community, 216 plots were available for sampling and 145 in the mountain hemlock community.

I estimated that a total of about 75 plots could be sampled during the available time. Therefore, 45 plots were selectd at random from the total number in the mixed conifer community and 30 from the total in the mountain hemlock community. This resulted in a sampling intensity of about 20 percent.

Within each shelterwood unit, the sample plots were located the same as sections are numbered in a township, beginning at the northeast part of the unit. Candidate sample plots were rejected if the shelterwood unit was seeded to trees or if it had been converted to nonforest uses. When a plot was rejected, it was replaced by another from a random list of alternate plots.

Data Collection

A grid of 25 sample points (subplots) was centrally located on each 10-acre plot. Circular subplots (quadrats) were systematically spaced at 66-foot intervals on five parallel lines 66 feet apart containing five subplots each. At each of the 25 sample point locations in the plot, three concentric subplots (1-milacre, 4-milacre, and 0.0785-acre) were examined for presence of regeneration, associated environmental variables, and condition of residual overstory. A sample point was rejected if conditions making it unsuitable for regeneration--streambeds, marsh or swamp, active roads, or gravel or cinder pits, solid rock, or erosion--occurred on more than one-half of a milacre subplot. Only 0.2 percent of the subplots were rejected for these reasons.

Information about the shelterwood unit and the timber stand in which it was located was obtained from Ranger District records and from field observations. Information obtained was the plant community in which the plot was located, average elevation of the plot, timber type, date of harvest, slash treatment method and year of treatment, species planted and year of planting, subsequent cultural treatments, and general notes on size, growth, and distribution of regeneration, or damage. The plant community was verified by observation of adjacent uncut stands.

On each 1-milacre subplot, the total number of seedlings of each species was counted and recorded by origin. Regeneration was classified as being of preharvest (advance) origin or of postharvest (subsequent) origin. Trees of subsequent origin were divided into 1- and 2-year-old seedlings from natural seed fall, seedlings 3 years and older from natural seed fall, and planted trees. On each 4-milacre subplot, the species and origin (advance, natural subsequent, or planted) of the seedling most likely to dominate the subplot because of its size and vigor were recorded. Four-milacre subplots were used for data on dominant seedlings to reduce the probability of unstocked subplots. On each 0.0785-acre subplot, the species and diameter at breast height (d.b.h.) of all standing overstory trees, including trees that died during the regeneration period, were recorded plus the species, number, and d.b.h. of windthrown trees.

Planted trees were identfied from information on species planted, date of planting, and spacing. In shelterwoods where survival was high, regular rows of planted trees were clearly visible. Identification of planted trees was less certain when survival was low, but counting whorls to check the age of a tree helped in determining planted trees.

The following environmental factors associated with each 1-milacre subplot were observed and recorded:[1] Aspect, slope, condition of the seed bed (mineral soil, litter, slash), degree of burn, understory vegetation (forbs, shrubs, grasses), residual overstory density (basal area and percent crown closure), and presence or absence of animal damage.

Data Analysis

To illustrate the present status of reforestation, I summarized data in tables showing seedling numbers and stocking percentage of milacre subplots by species and origin for the plant communities. To determine the relationship between regeneration and environmental variables, I used stepwise multiple regression procedures to fit linear equations of the form $Y=b_0+b_1X_1+b_2X_2+...b_nX_n$ to the data. Dependent (Y) variables used were stocking percentages of milacre subplots and number of seedlings per acre of the various species and origins, and the independent (X) variables were the environmental factors given in the appendix[2].

RESULTS AND DISCUSSION

Regeneration Stocking and Density

Regeneration on shelterwood units in both the mountain hemlock/grouse huckleberry and the mixed conifer/snowbrush-chinkapin communities was excellent for all species established before and after logging (fig. 3). An average of 63 percent of the milacre

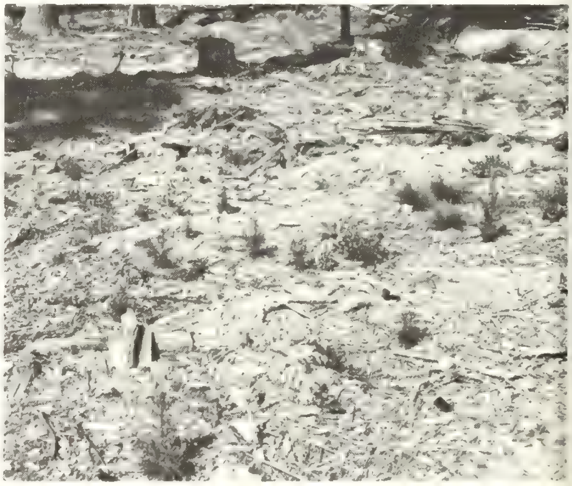

Figure 3.--Natural regeneration in a mixed conifer shelterwood unit. Seedlings here are primarily grand fir and Shasta red fir and are 4 to 5 years old. Note absence of understory vegetation.

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[1] See appendix for details of procedures for measuring and coding the environmental factors.

[2] Subplots were considered stocked if they contained at least one seedling.

subplots were stocked (all classes) in both plant communities, and seedling density (all classes) averaged 4,483 per acre in the hemlock type and 2,968 per acre in the mixed conifer type (table 2). Of the 4-milacre subplots, 88 percent were stocked in

Table 2--Average stocking percent and number of seedlings per acre of all species on shelterwood units in 2 plant communities in the Cascade Range of eastern Oregon, by class of reproduction[1]

Class of reproduction	Mountain hemlock/ grouse huckleberry			Mixed conifer/ snowbrush-chinkapin		
	Number of plots	Mean ± S.E.[2]	Range	Number of plots	Mean ± S.E.[2]	Range
			Stocking percent			
Advance	30	9.5 ± 1.3	0-24	45	7.6 ± 1.1	0-28
Subsequent:						
1- and 2-year-old seedlings	30	28.3 ± 3.2	0-52	45	26.5 ± 3.4	0-88
3-year-old seedlings and older	30	45.9 ± 4.5	0-76	45	45.1 ± 3.6	4-92
Planted seedlings	15	20.0 ± 3.8	0-40	43	12.7 ± 1.7	0-36
All classes except 1- and 2-year-old seedlings	30	56.8 ± 3.8	8-92	45	57.1 ± 3.0	16-92
All classes	30	63.6 ± 3.8	16-92	45	63.2 ± 3.2	16-96
			Number per acre			
Advance	30	186 ± 35	0-800	45	162 ± 39	0-1,240
Subsequent:						
1- and 2-year-old seedlings	30	979 ± 182	0-3,000	45	894 ± 273	0-10,760
3-year-old seedlings and older	30	3,192 ± 583	0-12,400	45	1,781 ± 321	40-10,600
Planted seedlings	15	205 ± 36	0-880	43	134 ± 19	0-440
All classes except 1- and 2-year-old seedlings	30	3,504 ± 579	200-12,440	45	2,071 ± 327	200-11,200
All classes	30	4,483 ± 735	280-15,360	45	2,968 ± 569	120-21,960

[1] Based on 1-milacre subplots.

[2] S.E. = standard error.

the hemlock shelterwoods and 86 percent in the mixed conifer.

Postharvest natural regeneration made up the bulk of the seedlings in shelterwood units in both communities. In the mountain hemlock plots, 93 percent of the reproduction was of natural subsequent origin compared with 90 percent in the mixed conifer plots. Advance reproduction was a relatively minor component of the regeneration in both communities. This was expected because slash in nearly all shelterwood units was piled and burned, and much of the advance reproduction was destroyed. Planted seedlings were also only a small portion (5 to 10 percent) of the total number of seedlings on the planted plots. Because of their uniform distribution, however, the percentage of milacres stocked with planted seedlings was higher than the small number of seedlings might suggest (table 2).

Although 22 to 30 percent of the reproduction in these shelterwood plots consisted of 1- and 2-year-old seedlings, the effect of these seedlings was to increase the density of the regeneration rather than to greatly raise stocking levels. In the mountain hemlock shelterwoods, for example, stocking was increased on 73 percent of the plots; but on only 4 of the 30 plots was the gain more than 12 percent. In the mixed conifer shelterwoods, stocking was raised on 60 percent of the plots; but on only 7 of the 45 was the gain more than 12 percent.

Postharvest natural regeneration was found on all plots except in the mountain hemlock community, but there was a considerable difference in number of seedlings between five plots with an overstory of pure hemlock and plots with a mixture of hemlock, true fir, white pine, and lodgepole pine. In the pure hemlock plots, an average of only 104 seedlings per acre of natural subsequent origin were found, compared with 3,650 in the plots with a mixed overstory. The poor natural regeneration of mountain hemlock in contrast to the other species is probably due to the low residual overstory density (less than 50 ft^2 per acre).

Natural regeneration was established soon after the seed cut in the shelterwoods in both plant communities. Although the average age of these units is only 6 or 7 years, the largest single component of the reproduction is natural postharvest seedlings 3 years and older (table 2). For seedlings of this age to be present, sufficient seed fall must have occurred within 1 to 3 years after the seed cut.

During the 8-year period in which these shelterwood units were cut, 2 heavy seed years occurred (1971 and 1974). Apparently most of the natural regeneration on the plots originated from these heavy seed crops. Obviously, a heavy seed fall occurring soon after the seed cut offers the best chance for successful establishment of seedlings because seed falls into loose mineral soil. Large amounts of seed also allow for losses to rodents and birds and for subsequent mortality. Although the bulk of the natural reproduction was from the 2 heavy seed years, seedlings of all possible ages were found in most plots. Thus, although heavy seed crops are ideal, it is possible to obtain satisfactory stocking from several light seed years as long as the seed bed remains receptive. Williamson (1973) also reported that adequate natural regeneration of Douglas-fir in the Cascades of western Oregon was obtained from establishment of seedlings during years of low seed fall. These observations suggest that it is desirable but not absolutely necessary to schedule seed cuts to coincide with heavy seed years.

In addition to overall average stocking of density of reproduction, a clearer picture of the status of regeneration on the shelterwood units can be obtained when plots are grouped into several stocking classes. Therefore, plots in both plant communities were grouped according to the number and percentage which attained specific levels of stocking or density (table 3). Depending on the definition of adequate stocking, the proportion of shelterwood units successfully regenerated can be determined. For example, if 40-percent stocking of milacre quadrats is considered satisfactory (at least 400 trees per acre), then 77 percent of mountain hemlock shelterwoods meet this standard compared with 84 percent of mixed conifer shelterwoods. Similarly, on a seedling density basis, 80 percent of the mountain hemlock shelterwoods and 76 percent of the mixed conifer plots had at least 700 seedlings per acre.

Because of the generally abundant natural regeneration, some plots were overstocked. In the mountain hemlock type, six shelterwood plots had more than 7,000 seedlings per acre and a density of 15,000 per acre was found on one plot; in the mixed conifer community, about 22,000 seedlings per acre were recorded on one plot. Overstocking of reproduction after the seed cut is not a serious problem, however, because some regeneration will be lost when the residual overstory is removed. If units are still overstocked after the final removal cut, stocking level control should be begun promptly to avoid loss of growth.

Table 3--Proportion of shelterwood plots stocked at various levels with 3-year-old and older advance and subsequent regeneration in 2 plant communities in the Cascade Range of eastern Oregon[1]

Stocking percent			Number of trees per acre		
Stocking at least	Plots	Proportion of total	Stocking at least	Plots	Proportion of total
Percent	Number		Number per acre	Number	
MOUNTAIN HEMLOCK/GROUSE HUCKLEBERRY--30 PLOTS					
20	29	0.97	200	30	1.00
40	23	.77	400	25	.83
60	16	.53	700	24	.80
80	4	.13	1,000	22	.73
			2,000	18	.60
			3,000	14	.47
MIXED CONIFER/SNOWBRUSH-CHINKAPIN--45 PLOTS					
20	44	.98	200	45	1.00
40	38	.84	400	42	.93
60	18	.40	700	34	.76
80	9	.20	1,000	28	.62
			2,000	14	.31
			3,000	9	.20

[1] Based on 1-milacre subplots.

Species Composition of Regeneration

The regeneration in both plant communities was composed of a mixture of species. In the mountain hemlock type, Shasta red fir was found on more milacre subplots than any other species (table 4). Grand fir and western white pine were also major species in the reproduction. For all origins combined, average stocking of the four major species is ranked as follows: Shasta red fir 43.5 percent, grand fir 14.1 percent, western white pine 10.0 percent, mountain hemlock 8.9 percent.

In the mixed conifer community, grand fir and red fir were the two major species--both occurred on the average on about 38 percent of the milacre subplots (table 4). Stocking of Douglas-fir (32 percent) was almost equal to that of the true firs, and ponderosa pine was the fourth most common species in the reproduction.

Table 4--Average stocking of advance and subsequent regeneration on shelterwood plots in 2 plant communities in the Cascade Range of eastern Oregon, by species[1]

Species	Mountain hemlock/grouse huckleberry				Mixed conifer/snowbrush-chinkapin			
	Advance seedlings	Subsequent seedlings[2]		All classes	Advance seedlings	Subsequent seedlings[2]		All classes
		3-year-old and older	1- and 2-year-old			3-year-old and older	1- and 2-year-old	
	Stocking percent ± S.E.[3]				Stocking percent + S.E.[3]			
Grand fir	0.8 ± 0.3	13.7 + 3.2	4.1 + 1.2	14.1 ± 3.7	5.6 + 1.0	29.2 + 3.0	10.5 + 1.6	38.0 + 3.5
Shasta red fir	5.9 ± 1.2	35.9 + 5.0	23.9 + 3.7	43.5 ± 5.9	1.1 + .4	27.5 + 9.1	10.8 ± 4.6	38.5 + 17.6
Pacific silver fir	.1 + .1	.2 + .2	.2 ± .2	.3 + .3	0 ± --	0 + --	0 + --	0 ± --
Douglas-fir	0 ± --	0 ± --	0 ± --	0 + --	.6 ± .3	21.4 + 6.2	9.7 ± 2.5	31.9 ± 13.3
Mountain hemlock	3.5 ± .9	4.4 ± 1.3	2.9 ± .8	8.9 ± 1.9	0 ± --	0 ± --	0 ± --	0 ± --
Engelmann spruce	0 ± --	1.5 + 1.0	.8 + .7	1.7 ± 1.2	0 ± --	.4 + .4	.1 ± .1	.4 ± .4
Western white pine	.5 ± .3	6.9 + 1.4	2.1 ± .7	10.0 ± 1.8	.5 + .2	2.2 + .6	1.9 + .8	4.4 ± 1.3
Ponderosa pine	0 ± --	1.3 + 1.3	0 + --	1.3 + 1.3	.2 ± .1	9.6 + 1.8	2.6 ± 1.0	14.7 ± 4.6
Lodgepole pine	0 ± --	6.1 ± 1.7	1.5 + .6	6.8 ± 1.8	.2 ± .1	3.7 + 1.3	3.8 ± 1.8	6.7 + 2.2

[1] Based on 1-milacre subplots.

[2] Includes natural and planted regeneration.

[3] S.E. = standard error.

Dominant Species

Although measurements of stocking and density give an indication of abundance and distribution of the regeneration, a classification that includes an estimate of vigor or size helps to give an insight into the species most likely to predominate in the immediate future. In mountain hemlock shelterwoods, the reproduction is composed of several dominant species; Shasta red fir, lodgepole pine, grand fir, and mountain hemlock occur most frequently (table 5). Regeneration of natural subsequent origin was dominant on about 56 percent of the stocked 4-milacre subplots; planted seedlings on 29 percent. Although planted lodgepole pine was only a small component of the regeneration in number per acre, it was classified as dominant on 13.2 percent of the stocked 4-milacre subplots--the second largest species-origin combination. Planted red fir was dominant on about 10 percent of the stocked subplots, although it was planted only in minor amounts.

Reproduction of natural subsequent origin was also dominant on the largest number of stocked subplots (63 percent) in the mixed conifer shelterwoods (table 5), and again planted trees dominated on 29 percent of the subplots. Grand fir seedlings of subsequent

Table 5--Percent of stocked subplots by species and origin of dominant seedlings in 2 plant communities in the Cascade Range of eastern Oregon[1]

Origin of seedlings	Grand fir	Shasta red fir	Douglas-fir	Mt. hemlock	Western white pine	Engelmann spruce	Ponderosa pine	Lodgepole pine	Total
				MOUNTAIN HEMLOCK/GROUSE HUCKLEBERRY					
Advance	0.9	5.0	--	7.7	0.6	0.4	--	--	14.6
Natural									
Subsequent	6.6	40.2	0.1	2.3	4.5	.5	--	2.3	56.5
Planted	2.7	9.8	--	--	1.6	--	1.6	13.2	28.9
Total	10.2	55.0	.1	10.0	6.7	.9	1.6	15.5	100.0
				MIXED CONIFER/SNOWBRUSH-CHINKAPIN					
Advance	6.1	1.0	0.4	--	.9	--	--	--	8.4
Natural									
Subsequent	27.7	14.4	11.1	--	2.7	--	3.7	3.3	62.9
Planted	1.1	2.1	7.8	--	.2	--	17.5	--	28.7
Total	34.9	17.5	19.3	--	3.8	--	21.2	3.3	100.0

[1] Based on 4-milacre subplots; 1- and 2-year-old seedlings included.

origin were dominant on about 28 percent of the stocked subplots--the single largest species-origin combination; planted ponderosa pine was the second largest category. Because of their greater height, planted seedlings are dominant on more of the stocked subplots than their small numbers would suggest.

Height growth of the regeneration was not systematically measured in this study, but observations of annual height growth of 2 to 3 inches were common on the 3-year-old and older seedlings (fig. 4).

Relation of Present Stocking and Density to Environmental Factors

The influence of observed environmental factors on regeneration and their relative

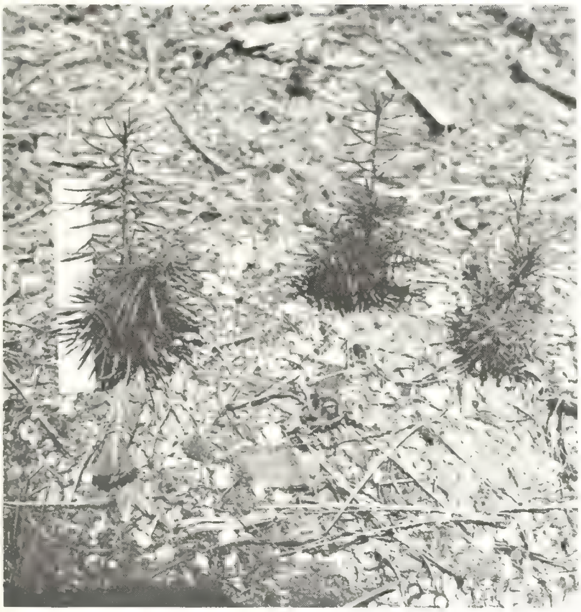

Figure 4.--Vigorous 5-year-old grand fir natural reproduction.

importance in descriptions of present stocking and seedling density were determined by stepwise regression analyses. The results of these analyses are presented in tables 6 and 7--the positive or negative relationship to stocking and density and the order in which variables appear in the equations.

In mountain hemlock shelterwoods, there was no correlation between understory vegetation and stocking or abundance of regeneration. This was expected, since, on the average only about 7 percent of the forest floor was occupied by forbs, shrubs, and grasses (table 1). In mixed conifer shelterwoods, however, the amount of understory vegetation was greater and was negatively correlated with density of regeneration (table 7). Heavy amounts of grass were especially detrimental to establishment of seedlings, and grasses entered as the first variable for all natural regeneration and 1- and 2-year-old reproduction.

Aspect appeared as a negative term in hemlock shelterwoods, indicating that regeneration was generally less on more northerly aspects (table 7). This was contrary to the expectation that northerly aspects are more favorable for natural regeneration as Seidel (1979b) found in mountain hemlock clearcuts. The reason is not clear, but one might speculate that perhaps a residual overstory does not allow sufficient insolation for optimum germination of seed on the cool, high elevation, northerly aspects in the mountain hemlock type. These results suggest that, in terms of natural regeneration, clearcutting is most useful on north to east aspects, whereas the shelterwood system has the advantage on south to west slopes. In the mixed conifer type, a more northerly aspect was associated with more regeneration.

An increase in elevation resulted in less regeneration in the hemlock type, and this variable was one of the first factors to enter the equations describing stocking (table 6); in the mixed conifer plots, elevation was positively related to reproduction. These are logical results since the environment for establishment of seedlings improves as the hot and dry conditions found at the lower elevations of the mixed conifer type give way to more

Table 6--Positive and negative correlations of variables and the order in which they appeared in regression equations describing stocking of regeneration in 2 plant communities in shelterwood units in the Cascade Range of eastern Oregon[1]

Species or origin	Variable[2]																
	Elevation	Aspect	Slope	Mineral soil	Litter	Slash	Litter and slash	Burn (pile and burn)	Forbs	Shrubs	Grasses	Basal area	Crown density	Residual trees per acre	Quadratic average diameter	R^2	Standard error of stocking percent
								MOUNTAIN HEMLOCK/GROUSE HUCKLEBERRY									
All regeneration	-2		-3	+5			+1				+4				+6	0.67	13.6
All natural regeneration	-2		-5	+6		+4	+1								+3	.73	14.8
3-year-old and older seedlings	-2					+5	+1				+3				+4	.68	15.2
1- and 2-year-old seedlings	-4		-2	+5			+3			-7	+6	+1				.60	12.8
Subsequent red fir			-3				+1								+2	.80	13.0
All red fir			-2	+4			+1					+3				.85	13.7
Subsequent white pine	-1	-3			-4		-7			-5			-2	-6		.76	4.4
All white pine	-2							+1					-3			.69	5.8
All mountain hemlock	-1			-4			-2	+5							-3	.77	5.4
								MIXED CONIFER/SNOWBRUSH-CHINKAPIN									
All regeneration		+5	+3					-4	-1			+2				.38	17.6
All natural regeneration		+5	+3	+4				-6	-1				+2			.38	21.8
3-year-old and older seedlings									-3		-2		+1			.26	20.8
1- and 2-year-old seedlings				+3							-2	+1				.34	18.4
Subsequent red fir	+1	+3				+5						+4			+2	.42	18.1
Subsequent grand fir	+3			+2				-4					+1			.46	15.5
Subsequent Douglas-fir	-1		+2				-4						+3			.34	13.3
All grand fir	+1			+3									+2			.40	18.8
All Douglas-fir	-1		+3									+2				.42	17.7
All red fir	+1	+5		+6		+7				-4				+3	+2	.50	19.5

[1] Numbers indicate the order in which variables entered the regression equation.

[2] Only the variables that accounted for the major portion of the variation in stocking percent are given. Variables were excluded if they failed to raise R^2 values by at least 3 percent.

mesic conditions at the upper limits of the community. Conversely, seedling establishment decreases at higher elevations in the mountain hemlock type because of more severe microclimates (primarily low temperatures).

Basal area had a consistent positive relationship to density of regeneration and entered as the first variable for nearly all equations in the mountain hemlock type (table 7), but crown density did not appear as one of the first factors. Crown density was related to the dependent variables about as strongly as was basal area. Because of the high degree of correlation between basal area and crown density (fig. 5), however, when one of these variables entered an equation, the other variable no longer contributed greatly to the explained variation. In the mixed conifer shelterwoods, both basal area and crown density were positively related to regeneration, but again not in the same equation.

It is apparent that the effect of these variables on stocking and density of regeneration depends on both the species and origin of reproduction and the plant community. In general, the effect of these variables on stocking and

Table 7--Positive and negative correlations of variables and the order in which they appeared in regression equations describing density of regeneration in 2 plant communities in shelterwood units in the Cascade Range of eastern Oregon[1]

Species or origin	Variable[2]																
	Elevation	Aspect	Slope	Mineral soil	Litter	Slash	Litter and slash	Burn (pile and burn)	Forbs	Shrubs	Grasses	Basal area	Crown density	Residual trees per acre	Quadratic average diameter	R^2	Standard error of seedling density
								MOUNTAIN HEMLOCK/GROUSE HUCKLEBERRY									
All regeneration	-5	-4			-2							+1			+3	0.65	2,607
All natural regeneration	-4		-5	+6	-2							+1			+3	.70	2,528
3-year-old and older seedlings	-3	-5			-4							+1		-2		.68	1,975
1- and 2-year-old seedlings	-6		-3	+4	-2							+1			+5	.63	678
Subsequent red fir					-3							+1		-2		.66	2,547
All red fir					-3							+1		-2		.68	2,507
Subsequent white pine	-2	-5						+1			-4	-3				.76	74
All white pine		-3					+4	+1			-2					.73	112
Subsequent mountain hemlock	-7	-6			-5		-3	+1		+4				+2		.81	72
All mountain hemlock	-1						-2		+3						-4	.77	85
								MIXED CONIFER/SNOWBRUSH-CHINKAPIN									
All regeneration					-5				-1	-4	-2		+3			.33	3,098
All natural regeneration					-5				-4	-3	-1		+2			.33	3,140
3-year-old and older seedlings	+4	+3		+2									+1		+5	.38	1,639
1- and 2-year-old seedlings					-4				-5	-2	-1	+3					
Subsequent grand fir	+3			+2						-5	-4		+1			.34	1,435
All grand fir	+3			+2						-5	-4		+1			.33	1,477
Subsequent Douglas-fir	-2		+4	+5							-3	+1				.46	562
All Douglas-fir	-2		+4	+3								+1				.42	572
Subsequent red fir	+3	+5		+2		+6							+1	+7	+4	.48	1,029
All red fir	+2	+5		+4		+6							+1	+7	+3	.47	1,049

[1] Numbers indicate the order in which variables entered the regression equation.

[2] Only the variables that accounted for the major portion of the variation in density of seedlings are given. Variables were excluded if they failed to raise R^2 values by at least 3 percent.

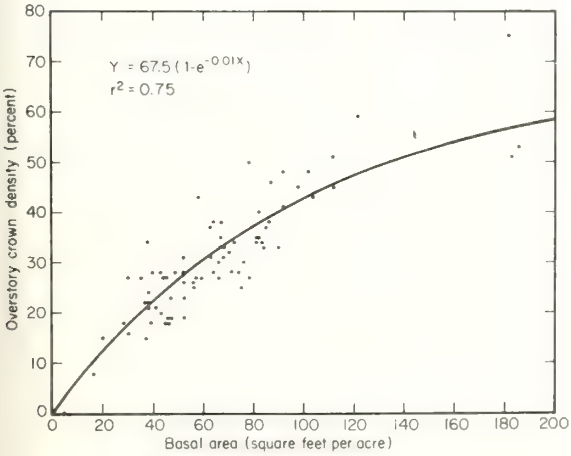

Figure 5.--Relationship between basal area and crown density of residual overstory for all shelterwood plots in both mountain hemlock and mixed conifer plant communities in the eastern Cascade Range.

abundance of regeneration in the mountain hemlock and mixed conifer communities can be summarized by listing the variables associated with increased stocking, decreased stocking, or having no strong relationship to stocking as follows:

MOUNTAIN HEMLOCK COMMUNITY

Increased stocking	Decreased stocking	Little relationship
More mineral soil	Higher elevation	Slash
More litter and slash	Greater slope	Burn
More basal area	More litter	Forbs
Greater average diameter of the overstory	More northerly aspect	Shrubs
		Grasses
		Crown density
		Overstory trees per acre

MIXED CONIFER COMMUNITY

Increased stocking	Decreased stocking	Little relationship
Higher elevation	More litter	Slash
More northerly aspect	Greater severity of burn	Litter and slash
Greater slope	More forbs	Overstory trees per acre
More mineral soil	More shrubs	Average diameter of overstory
More basal area	More grasses	
Greater crown density		

The indication that more litter and slash lead to increased stocking in the mountain hemlock community, whereas more litter decreases stocking appears to be a contradiction. The increased stocking associated with litter and slash probably is due to the effect of slash more than litter and may reflect some difficulty in classification of seed beds into the litter, slash, and litter and slash categories. In any case, the relationships between condition of the seed bed and establishment of natural regeneration are evident from the data and observations in this study and other studies. Mineral soil is clearly the most favorable seed bed for establishment of seedlings in both plant communities, but I observed many seedlings growing in light to medium litter layers (1/4 to 1/2-inch-deep). Heavy, continuous litter mats (more than 1/2-inch- thick) severely reduce the number of seedlings. Similarly, many seedlings were found growing in the shade of light amounts of slash throughout the shelterwood plots, but very few in deep concentrations of slash (fig. 6). Similar

igure 6.--Seedlings growing in shade of slash.

onditions were observed in nother shelterwood study in a ixed conifer plant community in entral Oregon (Seidel 1979a). herefore, it is not necessary or esirable to completely remove all itter and slash from the seed ed. Enough disturbance is caused y logging and slash disposal to rovide a receptive seed bed.

Some light damage to the regen-ration by animals was observed on hese shelterwood plots. In the ountain hemlock type, damage aused by gophers was found on about percent of the subplots compared ith 7 percent in the mixed coni-er community. Damage by other nimals (primarily deer) was ob-erved on 4 percent of the sub-lots in the hemlock plots and 7 ercent in the mixed conifer.

rediction Equations

Reliable equations to predict tocking or density of regeneration after shelterwood cutting would be useful. The regression equations summarized in the preceding section include variables--such as grasses, forbs, and shrubs--that change with time--similar to the change in stocking--and therefore cannot be used for predicting stocking. To derive prediction equations, I used only the variables that remain independent and can be measured before or directly after harvest.[3] Variables used were elevation, aspect, slope, slash, degree of burn, basal area, crown density, number of overstory trees per acre, and average diameter. Strictly speaking, amount of slash and degree of burn do not remain completely unchanged over time; but within the timespan this study covers, they changed little. Basal area, trees per acre, and average diameter were adjusted to values immediately after the seed cut by adding data from dead and down trees.

Because of the large amount of unexplained variation present, it is not possible to accurately predict regeneration stocking after shelterwood cutting in either the mountain hemlock or mixed conifer communities (tables 8 and 9). In

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[3] Variables that remain independent are those that are unchanged or nearly so over time or can be adjusted to preharvest values. For example, understory vegetation was not used because it can vary during the time after the seed cut, similar to tree regeneration.

Table 8--Prediction equations for milacre stocking of regeneration on shelterwood units in a mountain hemlock/grouse huckleberry community in the Cascade Range of eastern Oregon, by species and class of reproduction

Dependent variable	Equation[1]	Variation explained R^2	Standard error of estimate $S_{y \cdot x}$
		- - - Percent - - -	
1- and 2-year-old seedlings	=15.91+0.28(basal area)-11.48(slope)	0.37	14.5
3-year-old and older seedlings	=231.22+0.02(crown density)-0.04(elev.) +2.36(average diameter)+16.17(slash)-1.68(aspect) -22.44(burn)	.50	19.6
All natural regeneration	=258.12-0.05(elev.)+2.28(average diameter) +9.66(slash)-21.42(burn)	.45	20.2
All regeneration	=182.29+0.08(basal area)-0.02(elev.) -1.46(aspect)+0.98(average diameter)	.29	19.1
Subsequent red fir	=-16.25+2.33(average diameter)-31.87(burn)	.47	21.0
All red fir	=-4.81+0.29(basal area)-34.08(burn)	.49	24.6
Subsequent white pine	=103.83-0.01(elev.)-0.37(crown density) -0.66(aspect)	.57	5.5
All white pine	=108.39+9.29(burn)-0.02(elev.) -0.39(crown density)	.69	5.8
All hemlock	=85.71-0.01(elev.)-0.58(average diameter) +12.09(burn)	.66	6.3

[1] Variables are arranged in the order in which they entered the regressions. Only the variables that accounted for major portions of the variation in stocking percent are given. Variables were excluded if they failed to raise R^2 values by at least 3 percent.

the mountain hemlock plots, the equation predicting milacre stocking of all white pine accounted for the most variation (69 percent); the equation for all regeneration accounted for the least (29 percent). The equations showed that the establishment of able 9--Prediction equations for milacre stocking of regeneration on shelterwood units in a mixed conifer/snowbrush-chinkapin community in the Cascade Range of eastern Oregon, by species and class of reproduction

Dependent variable	Equation[1]	Variation explained R^2	Standard error of estimate $S_{y \cdot x}$
		- - - Percent - - -	
ubsequent red fir	=-214.96+0.03(elev.)+1.40(average diameter) +0.84(aspect)+0.15(basal area)+7.00(slash)	0.42	18.1
ubsequent grand fir	=-57.36+0.51(crown density)+0.01(elev.)	.26	17.5
ubsequent Douglas-fir	=99.29-0.02(elev)+8.12(slope) +0.26(crown density)	.31	13.4
ll grand fir	=-48.28+0.02(elev.)+0.55(crown density) -6.68(slash)	.32	20.0
ll Douglas-fir	=134.98-0.03(elev.)+0.20(basal area) +13.06(slope)	.42	17.7
ll red fir	=-231.71+0.04(elev.)+2.00(average diameter) +0.61(trees/acre)+7.50(slash)	.39	20.7
1- and 2-year-old seedlings	=-3.44+0.30(basal area)+0.77(aspect) +7.86(slope)	.25	19.7
3-year-old and older seedlings	=19.17+0.68(crown density)+9.32(slope)	.17	21.8
All natural	=17.26+0.74(crown closure)+15.53(slope) +0.98(aspect)	.23	23.5
All regeneration	=-33.06+0.27(basal area)+0.01(elev.) +10.33(slope)+0.79(aspect)	.32	18.1

[1] Variables are arranged in the order in which they entered the regressions. Only the variables that accounted for major portions of the variation in stocking percent are given. Variables were excluded if they failed to raise R^2 values by at least 3 percent.

white pine (a shade-intolerant species) was reduced by heavier residual overstories compared with the more shade-tolerant species which were favored by increasing stand densities. The amount of variation explained by the equations was similar for mixed conifers and mountain hemlock and ranged from 17 percent for 3-year and older regeneration to 42 percent for all Douglas-fir (table 9).

Although these equations are not accurate enough for predictions, they are probably as good as can be expected when the variables involved and complex distribution pattern of natural regeneration are considered. Unexplained variation exists for several reasons. In a survey study, no estimate of the amount of seed fall on the shelterwood units is obtainable. In addition, factors measured (aspect, slope, etc.) are secondary variables. These variables influence the five primary variables (light, temperature, moisture, and chemical and physical factors) in which seedlings respond directly. Finally, it should be mentioned that, ideally, equations such as these should be verified on an independent set of data not used in their derivation. Therefore, I want to emphasize that these equations should not be considered precise predictors of expected regeneration after shelterwood cutting but only crude estimates of possible stocking.

Residual Stand Density and Regeneration

The question of the appropriate stand density to leave after the seed cut is important to land managers. Although the equations in this study do not permit an accurate estimate of expected regeneration, some idea of the general trend of reproduction as stand density varies and the range of stand densities most suitable for regeneration can be obtained from these data and similar studies.

In both plant communities, there is a general trend of increasing stocking as stand density (basal area) increases and a large amount of unexplained variation in stocking (fig. 7). It appears that there is no problem in obtaining an abundance of natural regeneration at relatively high

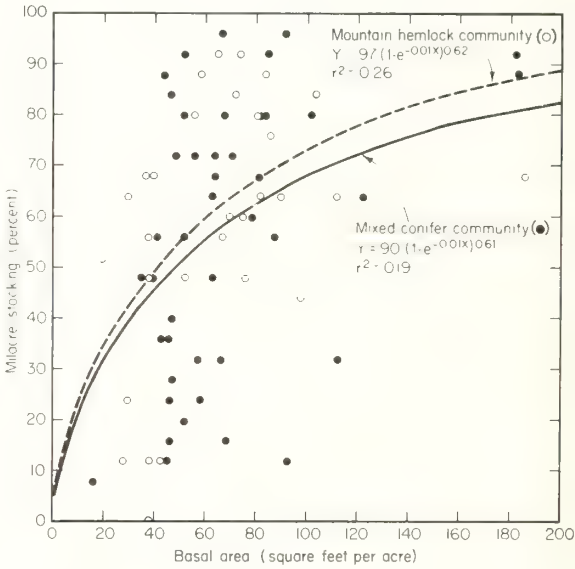

Figure 7.--Relationship between basal area and milacre stocking of natural regeneration in the mountain hemlcok and mixed conifer plant communities in the Cascade Range of eastern Oregon.

stand densities of over 100 square feet per acre. When the shelterwood system is used in the general forest zone, however, residual stand density should be reduced to the minimum level at which an acceptable amount of regeneration will be obtained. Also, the established reproduction must not be excessively damaged or destroyed during removal of the overstory and disposal of slash. My observations suggest that if at least 40-percent stocking of milacre plots is desired, then a basal area of about 60 square feet per acre should result in adequate stocking on most units. A few shelterwood plots were 50 to 70 percent stocked with residual basal areas as low as 30 to 40 square feet per acre, but the probability of failure of regeneration increases at this low density.

Basal area and elevation were two variables that appeared in many of the prediction equations. Their relationship to milacre stocking is illustrated in figure 8[4/] Although not accurate enough for predictions, these curves show the wide range of basal area where stocking occurs, the increase in stocking with elevation in the mixed conifer type, and the decrease in stocking at higher elevations in the mountain hemlock type. Even though milacre stocking of 40 to 60 percent is indicated by these curves at basal areas of 20 to 30 square feet per acre, the wide scatter of these data suggests that a residual stand density that low will probably result in some understocked units.

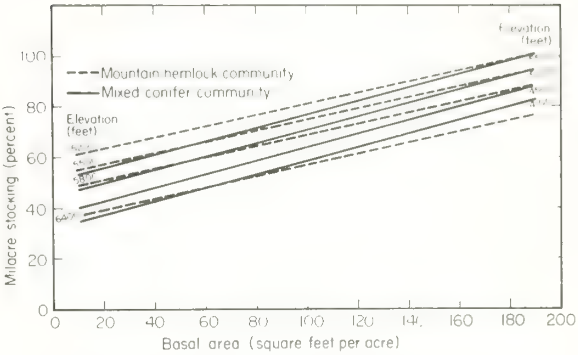

Figure 8.--Relationship between basal area, elevation, and milacre stocking of all regeneration in the mountain hemlock and mixed conifer plant communities in the Cascade Range of eastern Oregon.

The range of stand densities where adequate natural regeneration occurred in this study was similar to that found in several other shelterwood studies in central Oregon. In a single mountain hemlock stand, Seidel and Cooley (1974) estimated that about 80 square feet of basal area per acre was needed in the residual overstory for adequate reproduction of grand fir. And Seidel (1979a) found in a mixed conifer community that good regeneration

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[4/] Mountain hemlock equation is Y = 163.38 + 0.22 (basal area) -0.02 (elevation) $R^2 = 0.23^*$, standard error of estimate = 19.2 percent. Mixed conifer equation is Y = -20.62 + 0.26 (basal area) + 0.013 (elevation) $R^2 = 0.25^{**}$, standard error of estimate = 18.6 percent.

of true fir was established under a residual overstory of 50 square feet per acre. It is apparent from these studies that natural regeneration in the mixed conifer and mountain hemlock plant communities is established under a wide range of residual stand densities and that, because of the many variables affecting reproduction, no single level is suitable in all areas. A range of 60 to 80 square feet of basal area per acre is suggested as the minimum level for natural regeneration to occur on nearly all shelterwood units.

Natural Regeneration Versus Planting

Because of the good to excellent natural regeneration that occurred on most of the shelterwoods plots, planting does not seem necessary when considered only in terms of the contribution of the planted seedlings to total numbers of seedlings. Only 5 to 10 percent of the total number of seedlings in planted plots was planted stock. As discussed previously, however, the advantages of planting lie not with seedling numbers but with the good distribution and greater height of the planted seedlings.

In the mixed conifer community, planting increased stocking on 29 of the 43 planted plots; on 9 of these plots, stocking was raised by more than 12 percent. Obviously, the effect of planting is greatest on units where natural regeneration is light; planting can then be the difference between an understocked and an adequately stocked stand. For example, using a 40-percent stocking of milacre quadrats as representing adequate regeneration, planting increased stocking on 10 mixed conifer plots from less than 40 percent to above the 40-percent level. The only apparent common factor related to lack of natural regeneration on these plots was a light residual overstory. After the seed cut, 7 of the 10 plots had less than 60 square feet of basal area.

On the 15 shelterwood units planted in the mountain hemlock community, on only 1 was stocking increased above 40 percent by the planted seedlings. Although planting was generally not needed to insure an adequately stocked stand in this plant community, there appears to be a relationship between species composition of the overstory and a need for planting. On the plots where the overstory consisted of a mixture of species, natural regeneration was good to excellent, even at residual densities of less than 60 square feet per acre, and planting was not needed. On the other hand, natural regeneration was poor on plots where the overstory was 100 percent mountain hemlock and planted seedlings made up 70 percent of the reproduction.

The amounts of understory vegetation that became established on these shelterwood plots after the seed cut were small, especially in the mountain hemlock community where only about 7 percent, on the average, of the seed bed was occupied (table 1). The absence of heavily competing vegetation for a number of years, together with the high probability of a heavy seed crop every 3 to 4 years as reported by Franklin et al. (1974) in mixed conifer stands and the good distribution of seed trees over the area, results in a high probability of success of natural regeneration.

Because of the abundant natural regeneration that can be expected within a few years after the seed cut, planting appears better suited as a supplemental means of reforestation to raise stocking above minimum standards. The most efficient use of planting in the shelterwood system is probably to increase stocking where removal of the residual overstory has reduced stocking below minimum standards. Planted seedlings are then not subject to loss or damage by logging operations as they are when planted before the overstory is removed.

In summary, results of this study suggest that planting shelterwood units immediately after the seed cut is necessary only in the following cases: (1) in mixed conifer communities if residual basal area is reduced below 60 square feet per acre and (2) in pure mountain hemlock communities containing no other species in the overstory.

Overstory Mortality

Mortality of the residual overstory after the seed cut was greater in the mountain hemlock plots than in the mixed conifer community. An average of 2.4 trees per acre were blown down and 1.7 trees per acre were standing dead in the mountain hemlock type. This amounted to about 16 percent of the total number of trees left after logging. In the mixed conifer community, about 6 percent of the overstory was lost--an average of 0.5 tree per acre blown down and 0.6 tree per acre standing dead.

Blowdown can be a problem when the shelterwood system is used in unmanaged old-growth stands because trees growing at high densities have not developed the windfirmness needed to resist greater stresses from wind after heavy partial cuts. Mountain hemlock is especially susceptible because of its relatively shallow root system (fig. 9). The risk of blowdown can be reduced by leaving dominant or codominant, full-crowned trees which are the most windfirm and also the best seed producers (Gordon 1973). Mountain hemlock should be discriminated against in favor of the other species in the overstory when the seed cut is marked. This not only reduces the chance of blowdown but also increases the chance of regeneration success by providing more seed of species, such as the true firs, that apparently regenerate better than mountain hemlock at stand densities from 60 to 80 square feet per acre.

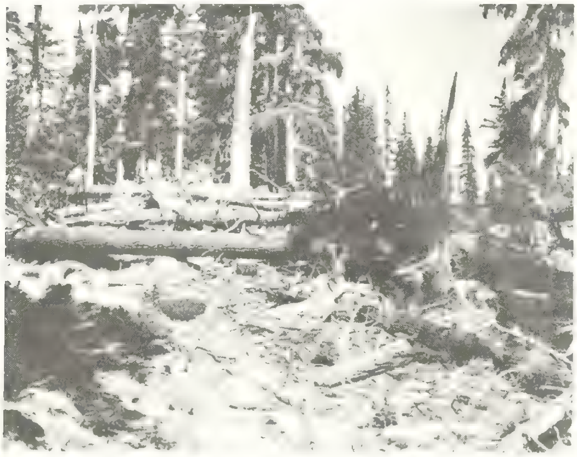

Figure 9.--Blowdown of mountain hemlock.

CONCLUSIONS AND RECOMMENDATIONS

The results of this survey indicate that use of the shelterwood system can provide satisfactory natural regeneration of a number of species in terms of stocking and seedling density in both mixed conifer/snowbrush-chinkapin and mountain hemlock/grouse huckleberry plant communities. Obtaining adequate natural regeneration depends on many factors. Two of the most important are a sufficient and uniform overstory density and a seed bed receptive to establishment of seedlings. A uniform residual overstory in the range of 60 to 80 square feet of basal area per acre is recommended for natural regeneration in both plant communities. Adjustments in the basal area level can be made for various aspects, slopes, or elevations by use of the prediction equations; that they provide only very rough estimates of expected stocking because of the considerable amount of unexplained variation must be considered. A suitable seed bed is provided by logging and slash disposal operations, which serve to break up heavy litter layers and expose mineral soil. A heavy seed year soon after the seed cut provides the best chance of securing regeneration immediately; but, because competing understory vegetation is not a serious problem, seed beds remain receptive and adequate stocking can be obtained over a period of years from a number of light seed crops.

Planting on these shelterwood units served mainly as a supplemental rather than a primary means of reforestation. Seedlings should be planted in mixed conifer shelterwood units immediately after the seed cut if overstory density is less than 60 square feet per acre and in mountain hemlock shelterwoods where the overstory consists only of mountain hemlock. Otherwise, natural regeneration should be relied on. If natural regeneration has not resulted in adequate stocking after 3 or 4 years in unplanted units, the land manager can then (1) underplant to raise stocking to satisfactory levels or (2) remove the residual overstory and then plant. Alternative 2 is recommended because planted seedlings are then not subject to loss or damage from logging and slash disposal operations. Ponderosa pine and Douglas-fir are the preferred species to plant in mixed conifer communities; lodgepole pine and the true firs survive and grow well in the mountain hemlock type. Planting stock grown from seed collected in the same geographical and elevational zone as the shelterwood unit should be used.

The residual overstory in shelterwood units should consist of only the most vigorous dominant or codominant trees. This objective is accomplished better if the leave trees rather than cut trees are marked. This focuses the marker's attention on the most desirable trees to leave and also reduces the tendency to leave too heavy an overstory, which sometimes occurs when the cut trees are marked.

It is clear from the results of this and other studies that adequate natural regeneration is obtained when the shelterwood system is used in mixed conifer and mountain hemlock plant communities in the Cascade Range of eastern Oregon. Establishment of a satisfactory stand of reproduction after the seed cut, however, is only part of the reforestation job when the shelterwood system is used. Unless the residual overstory can be removed without causing unacceptable loss and damage to the regeneration, all the time and effort involved in securing regeneration have been wasted. Although there are many mixed conifer shelterwood units in the Cascades where the seed cut has been made, the residual overstory has been removed on very few; so experience is lacking regarding the best procedures. Limited experience, however, has shown that it is possible to remove an overstory of 24,000 board feet per acre and still preserve ponderosa pine saplings (Barrett et al. 1976). And McDonald (1976) reported that up to 10 overstory trees per acre were removed from shelterwood units in California without excessive loss of reproduction.

The key to saving the regeneration is good coordination between timber and fuels management staffs and the skillful application of logging techniques designed to preserve the established reproduction. After studying logging methods in mixed conifer stands in Arizona, Gottfried and Jones (1975) suggested several changes to reduce loss and damage to regeneration. They include:

1. Marking and clearing skid trails.--Skid trails should be marked on the ground and the same trails used for all cuts. Windfalls are commonly found lying across skid trails when the overstory is removed. Pushing these tree length windfalls out of trails does considerable damage to the reproduction. Damage can be avoided by having a swamper preclear skid trails by sawing out sections of the blowndown trees and then pushing them into areas where damage would be least.

2. Directional falling and variable log lengths.--Trees should be felled in a herringbone pattern so that logs can be pulled onto skid trails with the least disturbance. Trees should be felled into openings in preference to maintaining a strict herringbone pattern. Trees lying at a poor angle for winching to skid trails should be bucked into 16-foot logs rather than 32-foot logs. Tractors should stay on trails and back toward direction of fall.

3. Careful winching.--Restrictin tractors to marked and precleared skid trails would require more winching. Logs being winched to a tractor sometimes catch on down material and drag it sideways destroying and damaging regeneration. A swamper or the choker setter could saw out sections that lay in the way, making winching easier and reducing damage to the reproduction.

4. Yarding unmerchantable material.--Moving unmerchantable logs to landings will reduce the amount of material that must be handled in the slash disposal operations.

5. Season of logging.--Logging o snow offers possibilities for reducing root damage and destruction of fewer trees. Logging operations should be avoided, if possible, during the spring when terminal shoots are tender and easily broken and at times when freezing conditions make stem brittle.

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APPENDIX

Independent (X) variables used in regression analyses.

1. Elevation. The average elevation of the plot to the nearest 10 feet as measured with an altimeter.
2. Aspect. One of eight compass points measured on each subplot. The method proposed by Day and Monk (1974) was used to code the aspect, and the following values were assigned to compass directions: N - 14; NE - 15; E - 11; SE - 7; S - 3; SW - 2; W - 6; NW - 10. Average coded value of the 25 subplots was used in analyses.
3. Slope. Percentage slope of each subplot was measured with a clinometer and coded as follows: 0-9 percent, 0; 10-19 percent, 1; 20-29 percent, 2; 30-39 percent, 3; etc. Average coded value of subplots was used.
4. Mineral soil. The percentage of each subplot containing mineral soil was estimated, coded in the same way as slope values, and averaged.
5. Litter. The percentage of each subplot covered with litter was estimated, coded in the same way as slope values, and averaged.
6. Slash. The percentage of each subplot covered with slash was estimated, coded in the same way as slope values, and averaged.

7. Litter and slash. The percentage of each subplot covered with litter and slash was estimated, coded in the same way as slope values, and averaged.

8. Degree of burn. Estimated on each subplot and coded as: None, 0; light, 1; medium, 2; heavy, 3. Averaged coded value was used in analyses. Degree of burn is defined as: None--no visible effect of fire; light--fire charred the surface of the forest floor but did not remove all the litter layer; medium--fire removed all the litter layer and some of the duff; heavy--fire removed all the litter and duff and imparted a color to the mineral soil.

9. Forbs. The percentage of each subplot covered with forbs was estimated, coded in the same way as slope values, and averaged.

10. Shrubs. The percentage of each subplot covered with shrubs was estimated, coded in the same way as slope values, and averaged.

11. Grasses and sedges. The percentage of each subplot covered with grasses and sedges was estimated, coded in the same way as slope values, and averaged.

12. Basal area. The overstory basal area at each subplot was measured with a 10-factor angle gage and averaged for use in analyses.

13. Crown density. The overstory crown density or closure was measured with a spherical densiometer at each subplot by Strickler's (1959) method. Average value of the 25 subplots was used in analyses.

14. Overstory trees per acre. The numbers of standing overstory trees (living and dead) and blown down trees were recorded on 0.0785-acre subplots at each of the 25 sample points, averaged, and converted to a per-acre basis.

15. Overstory average diameter. The diameters at breast height of living and dead standing trees and blown down trees on each 0.0785-acre subplot were measured to the nearest inch and averaged.

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A survey of shelterwood cuttings in mixed conifer forests in the eastern Oregon Cascade Range showed that, on the average, shelterwood units were well stocked with a mixture of advance, natural subsequent, and planted reproduction of a number of species. Because of slow invasion by understory vegetation, frequent heavy seed crops, and adequate density of the overstory, natural regeneration was prolific on most units. Planting is recommended only as a supplemental reforestation method. Greater stocking was associated with increasing overstory density and more exposed mineral soil; such factors as aspect, slope, and elevation had a positive or negative relationship to stocking depending on the species and plant community.

KEYWORDS: Regeneration (stand), regeneration (natural), regeneration (artificial), mixed stands, Oregon (Cascade Range), shelterwood cutting method.

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search Paper PNW-265
October 1979

Effects of Manganese and Manganese-Nitrogen Applications on Growth and Nutrition of Douglas-fir Seedlings

M. A. Radwan, John S. Shumway, and Dean S. DeBell

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English Equivalents

1 liter = 0.2642 gallon
1 kilogram = 2.2046 pound
1 gram = 0.0353 ounce
1 centimeter = 0.3937 inch
1 kilogram per hectare = 1.1206 pound per acre

FFECTS OF MANGANESE AND MANGANESE-NITROGEN PPLICATIONS ON GROWTH AND NUTRITION F DOUGLAS-FIR SEEDLINGS

eference Abstract

adwan, M. A., John S. Shumway, and Dean S. DeBell.
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Res. Pap. PNW-265, 12 p. Pac. Northwest Forest and Range
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EYWORDS: Soil manganese, nitrogen fertilizer response, seedling growth, Douglas-fir, Pseudotsuga menziesii.

ESEARCH SUMMARY

esearch Paper PNW-265

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Effects of different amounts of Mn as manganous sulfate on Douglas-fir
rown in soil with and without urea fertilizer were determined. Effects
f Mn were also studied when Douglas-fir was grown in nutrient solution.
n addition, Mn sorption by different forest soil types was evaluated.
esults show that Mn applied to the soil had no positive or negative ef-
ects on growth of seedlings regardless of urea additions. The highest
mount of Mn tolerated without any visible sign of injury was 12 070 kilo-
rams per hectare added to the soil and nearly 4,000 parts per million
p/m) in the foliage. Mn sorption by different soils was high; it varied
mong the soils studied and ranged from 30.8 to 64.0 percent. Mn toxicity
n Douglas-fir grown in nutrient solution did not develop until Mn con-
entration in the solution reached 400 p/m. The seedlings tolerated
,100 p/m in their shoots and 2,410 p/m in their roots. Because of high
orptions of Mn by different forest soils and high tolerance by Douglas-
ir to accumulations of Mn in its shoots and roots, it is doubtful that Mn
oxicity can be of importance under forest conditions, with or without
rea fertilization.

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INTRODUCTION

Manganese (Mn) is an essential micronutrient for all plants, including Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Much is known about the importance of Mn in plant life and its functions in plants. Briefly, Mn is believed to be involved, at least indirectly, in the synthesis of chlorophyll (Meyer and Anderson 1952), a participant in the light reactions of photosyntheses (Heath and Hind 1969), an activator of many enzyme systems (Epstein 1972), and a factor in nitrogen metabolism (Jones et al. 1949).

Deficiencies and toxicities of Mn are well documented in the agronomic literature (e.g., Labanauskas 1966, Foy et al. 1978). Although Mn deficiency has been observed in shade and orchard trees on calcareous soils, reports of deficiencies in trees in forest situations are rare (Stone 1968). Conversely, the possibility of Mn toxicity in forest trees has been suggested in numerous instances. High levels of Mn in soils and tree tissues have been linked to reduced growth (Adams and Walker 1975), injury (Ross 1961), and death (Child and Smith 1960) of some forest tree species.

Concentrations of Mn have been determined in foliage of Douglas-fir trees and seedlings (Beaton et al. 1965, Krueger 1967). Deficiency levels of Mn, interaction of Mn with other nutrients--e.g., nitrogen (N)--and effects of Mn amendments on growth and nutrition of Douglas-fir, however, have not been determined. A low-level, chronic Mn toxicity might be postulated in Douglas-fir and other northwestern species for several reasons. Forest soils of the Douglas-fir region are quite acid and are saturated for much of the year; both of these factors enhance availability of soil Mn (Buckman and Brady 1969). Moreover, recently collected data on nutrition indicate a significant negative relationship between growth and amount of Mn in foliage of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) (Radwan and DeBell 1978) and Douglas-fir.[1]

In this paper, we report results from several experiments aimed at clarifying the status of Mn nutrition in Douglas-fir. We investigated effects of different rates of Mn applied to soil, with and without urea fertilizer, on growth of Douglas-fir seedlings, soil pH, and chemical characteristics of foliage of treated trees. We also studied availability of Mn in the soil and its sorption by different soil types, and the tolerance to and uptake of Mn by Douglas-fir seedlings grown in nutrient solution.

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[1] Unpublished data on file at Forestry Sciences Laboratory, Olympia, Washington.

METHODS AND RESULTS

Experiment 1

We applied Mn and N at different rates to Douglas-fir seedlings and measured the effects of treatments on growth, soil pH, available Mn in soil, and chemical characteristics of the foliage.

Methods

Test seedlings.--Uniform, 3-year-old Douglas-fir seedlings from a low elevation Oregon seed source were used. The seedlings were started in the greenhouse in styrofoam planters in the spring of 1974 and moved outdoors in 1975. The seedlings were individually potted in 3.8-liter plastic pots in the winter of 1976. Each pot contained about 2.8 kg of Tumwater sandy loam soil. The native level of available Mn in this soil is quite low (17 p/m) compared with other soils used in our studies (42 to 136 p/m). Seedlings were watered with half-strength Hoagland's nutrient solution (Hoagland and Arnon 1950) in April and then fertilized twice in the 1976 growing season with a urea solution at a rate equivalent to 56 kg N/ha. In April 1977, heights and diameters of seedlings were measured to determine size of individual seedlings prior to treatment. Seedlings were then numbered and assigned different treatments at random. There were 10 seedlings per treatment and a total of 80 plants.

Fertilization treatments.--Eight treatments (four levels of Mn and two levels of N) were tested. Manganese and nitrogen were applied as manganous sulfate and urea, respectively, and all chemicals were applied to the soil in solution. Application rates of N were equivalent to 0 and 168 kg/ha, and those of Mn were equivalent to 0, 28, 112, and 560 kg/ha. In May 1977, just before bud burst, seedlings were moved to a lathhouse and treatments were applied. In each case, the required amount of urea (contained in 50 ml solution) was added, followed by the specified amount of manganous sulfate (contained in 100 ml solution) and 50 ml of water. Throughout the growing season, seedlings were watered as needed without leaching; the plants were harvested in January 1978.

Soil pH measurements.--One pot of each treatment was used to periodically determine pH after treatment. Each time, soil collected with a sampling tube (to the full depth of the pot) was thoroughly mixed with distilled water (1:1) and pH of the suspension was measured with a glass electrode about 30 minutes later. Soils were returned to their respective pots after each measurement.

Growth measurements.--Height and diameter of seedlings in pots not sed in the pH determinations (nine seedlings/treatment) were measured at he end of the growing season. At harvest, dry weights of shoots and ashed roots were determined after they were dried at 65°C to constant eight in a forced-air oven.

Determination of available Mn in the soil after harvest.--For each reatment, three composite samples were obtained; each consisted of horoughly mixed soil from three pots. Fifty-gram portions of each sample ere extracted for 2 hours with DTPA (diethylenetriaminepentaacetic acid) Lindsay and Norvell 1978). Mn in the filtered solutions was determined y atomic absorption (Perkin-Elmer Corporation 1976).

Chemical analyses of foliage.--Analysis was limited to current year's eedles to determine total N, calcium (Ca), Mn, iron (Fe), and zinc (Zn). eedles were obtained from all parts of each seedling before the shoots ere ovendried. After drying, weights of needles to be used in the analy-es were added to weights of the corresponding seedling shoots to obtain ry weights of shoots. Three composite samples of each treatment were nalyzed; each sample consisted of needles from three of the nine seed-ings receiving the treatment. Composite samples were individually ground o 40 mesh in a Wiley mill and stored in sealed containers at -15°C ntil needed for analysis. Total N (including nitrate) was determined by he micro-Kjeldahl procedure (Bremner 1965); Ca, Mn, Fe, and Zn by atomic bsorption (Perkin-Elmer Corporation 1976).

Statistical analysis.--Except for pH values, all data were subjected o analysis of variance; and means were separated by Duncan's multiple ange test.

Results

Growth characteristics.--Data on growth of the treated seedlings are hown in table 1. As expected, all growth characteristics of seedlings ere enhanced by nitrogen fertilizer, and needles of seedlings receiving dded N were greener than those not fertilized with urea. Manganese, on he other hand, had no effect on height growth or shoot weight. Diameter rowth and root weights were similarly unaffected in the absence of N fer-ilizer. However, diameter growth of the fertilized trees receiving 12 kg Mn/ha were significantly lower than those receiving 560 kg Mn/ha. lso, root weights of N-treated seedlings receiving 28 and 112 kg Mn/ha ere significantly lower than those of seedlings not treated with Mn. hese differences are unlikely to be real, because diameter growth and oot weights of nitrogen-fertilized seedlings treated with 560 kg Mn/ha ere not significantly different from those with no added Mn. Further-ore, visible symptoms of injury were not observed in any treatment.

Table 1--Growth characteristics of Douglas-fir seedlings treated with manganese and nitrogen[1]

Treatment Mn	Treatment N	Height growth	Diameter growth	Shoot weight	Root weight
Kilograms per hectare		- - - Centimeters - - -		- - - - - Grams - - - -	
0	0	14.6 a	1.73 a	18.3 a	11.2 abc
28	0	16.0 a	2.05 a	19.8 a	11.2 abc
112	0	15.8 a	2.00 a	20.5 a	10.5 ab
560	0	14.7 a	2.03 a	19.2 a	10.2 a
	Average	15.3 x	2.00 x	19.4 x	10.8
0	168	22.1 b	3.25 bc	27.2 b	14.3 e
28	168	23.5 b	3.15 bc	27.3 b	11.9 bcd
112	168	21.0 b	2.94 b	26.3 b	12.4 cd
560	168	24.6 b	3.49 c	27.7 b	13.2 de
	Average	22.8 y	3.24 y	27.1 y	12.9

[1] Values in the same vertical column followed by the same letter are not statistically different ($P<0.05$).

Thus, Mn levels used in this experiment neither stimulated nor reduced growth of Douglas-fir seedlings.

Soil pH.--pH values ranged from a high of 6.1 to a low of 5.1 (table 2). Values varied little by date of measurement, and both Mn and N tended to decrease pH slightly. Appreciable pH changes in surface soil due to urea or manganous sulfate were not detected since soil samplings for pH measurements were to the full depth of the pots.

Available Mn in soil.--At harvest, there were still 7 to 26 p/m Mn available in the soil (table 3). Available Mn increased with additions of manganous sulfate. Applications of urea N, however, reduced available Mn; this effect is presumably associated with increased growth and uptake of Mn by nitrogen-fertilized seedlings.

Table 2--Effect of manganese and nitrogen treatments on soil pH, by date of sampling

Treatment		pH		
Mn	N	5-4-77	7-19-77	1-19-78
Kilograms per hectare				
0	0	6.1	5.7	5.9
28	0	6.1	5.7	6.0
112	0	5.7	5.4	5.9
560	0	5.3	5.2	5.8
	Average	5.8	5.5	5.9
0	168	6.0	5.4	5.8
28	168	5.8	5.5	5.8
112	168	5.7	5.4	5.7
560	168	5.4	5.1	5.7
	Average	5.7	5.4	5.8

Table 3--Effect of manganese and nitrogen treatments on available Mn in soil[1]

Treatment		Available Mn in soil
Mn	N	
Kilograms per hectare		Parts per million
0	0	7 a
28	0	11 a
112	0	12 a
560	0	26 b
	Average	14 x
0	168	7 a
28	168	8 a
112	168	10 a
560	168	23 b
	Average	12 y

[1] Values in the same vertical column followed by the same letter are not statistically different ($P<0.05$).

Chemical characteristics of foliage.--Applications of Mn, with and without additions of N, did not significantly affect levels of N, Ca, Fe, or Zn (table 4). Concentrations of Mn in foliage, on the other hand, were affected. Thus, Mn levels increased from 207 to 1,203 p/m with an increase of added Mn in absence of N and from 193 to 968 p/m when N was applied. Additions of N did not significantly affect foliar concentrations of any of the nutrients except Mn; average Mn levels were significantly lower with N than without. Effects of N additions were probably due to more dilution by growth with urea than without.

Table 4--Chemical characteristics of Douglas-fir seedlings treated with manganese and nitrogen[1]

Treatment		N	Ca	Mn	Fe	Zn
Mn	N					
Kilograms per hectare		- - Percent - -		- - - Parts per million - - -		
0	0	1.02 a	0.24 a	207 ab	156 ab	50 a
28	0	1.11 ab	.26 a	244 b	177 b	50 a
112	0	1.03 a	.25 a	338 c	117 ab	47 a
560	0	1.19 ab	.26 a	1,020 e	155 ab	56 a
	Average	1.09 x	.25 x	453 x	151 x	51 x
0	168	1.34 b	.26 a	193 a	126 ab	44 a
28	168	1.28 ab	.27 a	188 a	141 ab	48 a
112	168	1.06 ab	.25 a	209 ab	143 ab	43 a
560	168	1.14 ab	.25 a	968 d	105 a	46 a
	Average	1.20 x	.26 x	390 y	129 x	45 x

[1] Values in the same vertical column followed by the same letter are not statistically different ($P<0.05$).

Experiment 2

This experiment involved additions of very high levels of Mn and was initiated when highest Mn treatments in the first experiment failed to induce any symptons of Mn toxicity.

Methods

Seedlings, pots, and soil used in this experiment were similar to hose of experiment 1. We applied manganous sulfate in amounts equivaent to 0, 1 207, 3 018, 6 036, and 12 070 kg Mn/ha to each of five ots. The pots were watered and kept in the lathhouse as in experiment 1. e added excessive amounts of Mn to determine tolerance of Douglas-fir o Mn. Current year's needles were harvested 6 months after Mn was aplied and were processed and analyzed for Mn and Fe as in experiment 1.

Results

Foliar levels of Mn increased with the increase of Mn added, and the ghest level found was nearly 4,000 p/m (table 5). Concentrations of on in the foliage, however, varied little among the treatments. Seedng appearance was the same in all pots. Seedlings did not show any sible symptoms of injury, indicating that Douglas-fir is quite tolerant o high levels of Mn in the soil.

Table 5--Effect of excessive supply of manganese in the soil on contents of Mn and Fe in Douglas-fir foliage

Mn additions			
$MnSo_4 \cdot H_20$, grams per pot	Kilograms Mn per hectare	Mn	Fe
		Parts per million	
0	0	174	37
4.6	1 207	745	31
11.5	3 018	1,590	32
23.0	6 036	1,680	25
46.1	12 070	3,970	32

xperiment 3

Because toxicity was not induced even when Mn was applied at rates quivalent to 12 000 kg/ha, we decided to determine the extent of Mn orption in the experimental soil and other forest soils.

Methods

We used the following soils which represent the range of inherent productivity found in the Douglas-fir region: Tumwater sandy loam, Boistfort clay loam, Alderwood gravelly sandy loam, and Kinney Creek loam. Available native Mn in these soils varied widely, ranging from 17 p/m in Tumwater sandy loam to 136 p/m in Boistfort clay loam. We added manganous sulfate in amounts equivalent to 250 or 500 p/m Mn to 50-g portions of each of the four soils. The manganous sulfate was thoroughly mixed into the soil, and water was added to bring soil moisture to field capacity. The treated soils were covered and left to equilibrate at room temperature. After 4 days, Mn was extracted from the soils with DTPA, and Mn in the filtered extracts was determined by atomic absorption as in experiment 1. Native Mn in the soils was also determined and subtracted from total extracted Mn before percent Mn sorbed by the different soils was calculated.

Results

Sorption of Mn varied among and within the different soils, and percent sorption ranged from 30.8 to 64.0 (table 6). Percent sorption varied little between the 250 and 500 p/m treatments in the Tumwater sandy loam and Alderwood gravelly sandy loam but differed widely between the two treatments in the Boistfort clay loam and the Kinney Creek loam. Reasons for the latter differences are unexplainable but not unreasonable, based on other studies (e.g., Shuman et al. 1978). Over both treatments, Tumwater sandy loam had the lowest sorbed Mn and Boistfort clay loam the highest. Sorption appears to be strongly related to soil texture; increased sorption occurs in soils having a higher content of clay.

Table 6--Sorption of manganese by different soils

Soil	Mn added	Mn extracted[1]	Mn sorbed
	Parts per million		Percent
Tumwater sandy loam	250	173	30.8
Tumwater sandy loam	500	342	31.6
Boistfort clay loam	250	120	52.0
Boistfort clay loam	500	190	64.0
Alderwood gravelly sandy loam	250	162	35.2
Alderwood gravelly sandy loam	500	302	39.6
Kinney Creek loam	250	157	37.2
Kinney Creek loam	500	221	55.8

[1] Excludes extracted native manganese.

xperiment 4

Tests in soil did not demonstrate Mn toxicity in Douglas-fir. Since nsiderable Mn sorption may occur in some forest soils, we investigated e effects of varying levels of Mn in hydroponic culture.

Methods

We used a series of 0.1-strength Hoagland's nutrient solution (Hoagnd and Arnon 1950) containing different concentrations of Mn to test lerance of Douglas-fir to Mn and to determine critical levels of Mn and xicity symptoms. We used manganous sulfate to obtain Mn concentrations 0.05, 20, 40, 100, 200, 400, 1,000, and 2,000 p/m. Treatment lutions were contained in quart mason jars covered with aluminum foil. o 1-year-old Douglas-fir seedlings were suspended in each jar. The edlings were in a state of active growth, and the jars were placed in a ant growth chamber. Temperatures in the chamber were 26°C during the y and 16°C at night; a 14-hour photoperiod was maintained. Culture lutions were continuously aerated and were changed after 15 days; seedngs were harvested after 1 month. Roots of treated plants were thorghly washed in distilled water, and plants were separated into roots d shoots at the root collar. Composite samples of shoots and roots re obtained by combining shoots and then roots of each two seedlings of ch treatment, and the different composite parts were ground to 40 mesh a Wiley mill. Levels of Mn in the ground roots and shoots were deterned by atomic absorption as in experiment 1.

Results

Roots and shoots of seedlings of all treatments appeared normal until days after the experiment was started, when needles of seedlings ceiving the 400, 1,000, and 2,000 p/m Mn showed some symptoms of toxicy. These symptoms consisted of wilting of the needles at the tips of e main stem and lateral branches, followed by death and desiccation of e wilted needles. With time, toxicity progressed from the tips of the ems and branches toward the bases; by the end of the experiment, large rtions of the shoots of the affected seedlings were dead. Roots were lso affected by excess Mn; they appeared blackened and lacked elongation mpared with those of normal seedlings. Toxic effects on both shoots nd roots increased as the concentration of Mn in the nutrient solution as increased from 400 to 2,000 p/m.

Roots and shoots of all seedlings contained Mn (table 7). Levels in e shoots increased as concentrations of Mn in the nutrient solution re increased. Manganese in the roots also increased but reached its ighest level at 200 p/m Mn in the nutrient solution. In seedlings which owed toxicity symptoms, Mn ranged from 20,700 to 40,000 p/m in the oots and from 1,540 to 2,320 p/m in the roots. Seedlings that did not ow toxicity symptoms tolerated a nutrient solution containing 200 p/m ; concentrations were 8,100 p/m in shoots and 2,410 p/m in roots.

Table 7--Effect of different concentrations of manganese in nutrient solution on levels of Mn in shoots and roots of Douglas-fir seedlings

Mn concentration in nutrient solution	Mn in shoots	Mn in roots
	Parts per million	
0	151	192
20	1,760	996
40	2,900	1,320
100	6,650	1,870
200	8,100	2,410
400	20,700	2,320
1,000	32,100	1,540
2,000	40,000	2,320

DISCUSSION AND CONCLUSIONS

Our studies indicate that Douglas-fir has high tolerance for Mn in soil, with and without additions of urea, and in nutrient solution culture. Applications of manganous sulfate to the soil in amounts equivalent to more than 12 000 kg Mn/ha resulted in concentrations of about 4,000 p/m Mn in foliage; but seedling growth was not reduced, nor were there visual symptoms of injury. Similarly, toxicity symptoms were not observed in solution culture at concentrations of up to 200 p/m Mn; under these conditions, the seedlings tolerated about 8,000 p/m Mn in their shoots and 2,400 p/m in their roots.

Results of the sorption experiment show that forest soils have capacity to fix or tie up Mn. Although sorption data obtained were not as high as those determined in agricultural soils (Shuman et al. 1978), significant amounts of Mn were sorbed by the soils used. Such sorption may limit accumulation of excess available Mn in soil and reduce the probability of Mn toxicity. This, together with the high tolerance of Douglas-fir for Mn mentioned above, suggests that it is unlikely that Mn toxicity can be important in management of Douglas-fir forests.

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GPO 989-540

Radwan, M. A., John S. Shumway, and Dean S. DeBell.
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KEYWORDS: Soil manganese, nitrogen fertilizer response, seedling growth, Douglas-fir, Pseudotsuga menziesii.

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January 1980

Competition for National Forest Timber in the Northern, Pacific Southwest, and Pacific Northwest Regions

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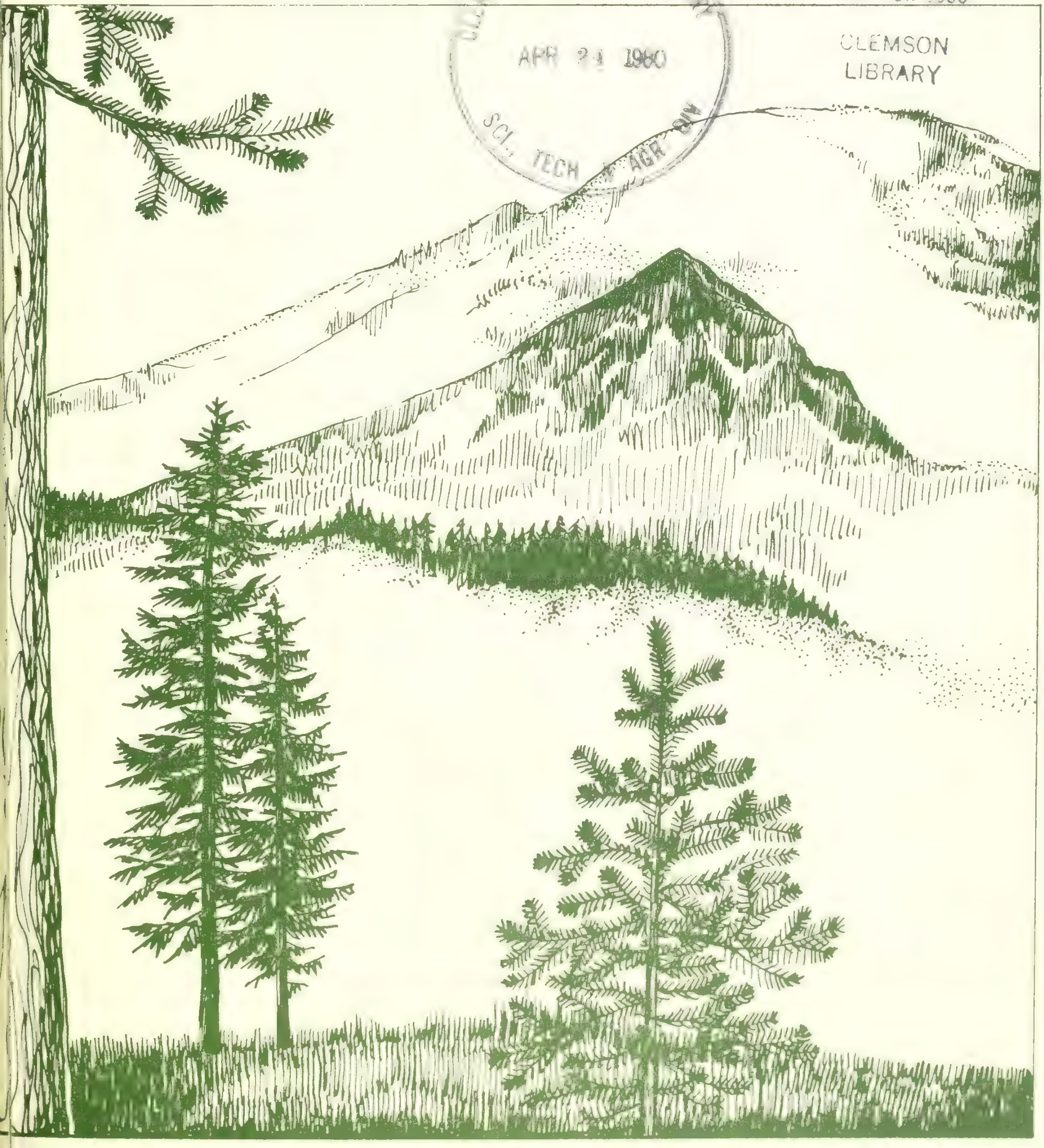

COMPETITION FOR NATIONAL FOREST TIMBER IN THE NORTHERN, PACIFIC SOUTHWEST, AND PACIFIC NORTHWEST REGIONS

eference Abstract

aynes, Richard W.
1980. Competition for National Forest Timber in the Northern, Pacific Southwest, and Pacific Northwest Regions. USDA For. Serv. Res. Pap. PNW-266, 72 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Competition for National Forest timber was examined n the Northern, Pacific Southwest, and Pacific Northwest egions of the Forest Service, U.S. Department of Agriulture. The impacts of sealed bidding and the Small usiness Set-Aside Program were found to vary widely mong the different appraisal zones. Noncompetitive ales were screened for collusive activity; and in eneral, little indication was found of such activity.

EYWORDS: Stumpage sales arrangement, National Forest administration, stumpage prices.

RESEARCH SUMMARY

Research Paper PNW-266

1980

Competition for National Forest timber was examined under the assumption that timber sales have quality aspects influencing how prospective bidders judge the potential profitability of a sale. Bidder activity and bid prices varied directly with potential profitability and responded eithe to changes in quality aspects or to changes in administrative variables.

Two issues examined have the potential to alter the administrative variables and hence bid prices and bidder activity. The first issue was th congressional mandate requiring the use of sealed bidding on USDA Forest Service timber sales. In general, sealed bidding increased competition and bid prices for National Forest timber in areas that historically have experienced relatively limited competition. In areas where competition was vigorous, sealed bidding had little impact. Further, there was little indication that the mix of oral and sealed bidding implemented in 1977 had much impact on overbid compared with the preceding 2 years or that sealed bidding had much impact on the incidence of outside bidders. The second issue dealt with equity considerations in the Small Business Administration Set-Aside Program. The USDA Forest Service tries to give equitable treatme to large and small firms in administering its sale program. This treatment however, seems highly variable throughout the study area. In some areas, set-aside sales had greater potential profitability than open sales, but bi prices for these sales did not reflect the increased profitability. In oth areas, prices for timber on set-aside sales did reflect differences in timb quality.

A related issue examined, which has limited impact on bid prices or bidder activity, was the problem of screening sales for collusive activity. In general, little indication was found of collusive activity. Most noncompetitive sales are noncompetitive because they appear to bidders to have a low potential profitability.

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INTRODUCTION

The Forest Service, U.S. Department of Agriculture, is the major ngle supplier of stumpage, accounting for roughly 25 percent of domestic od needs. National Forest timber is sold in open auctions to the highest dder at a price not less than an appraised price determined by subtracting st of production and a margin for profit and risk from the estimated lling value of an average mix of products that can be manufactured from e timber. Until 1977, National Forest timber sales were conducted the USDA Forest Service using either sealed bidding or oral bidding ocedures, depending on the competitive situation, business conditions, d local preferences. Sealed bidding methods were used in the East and oral dding methods in the West, though not exclusively. Since 1971, the revised all Business Administration Set-Aside Program has limited the bidding on a edetermined share of sales to small forest products firms.

In the past few years, three issues have come to the forefront con- rning bidding practices on National Forest timber sales. The most important sue and the most controversial has been the impact of a congressional mandate quiring the use of sealed bidding on all sales (U.S. Laws, Statutes, etc. 76). Although not easy to define, the magnitude of the impact was thought be great in areas where oral auctions had been the dominant sale method. e second issue has been the problem of establishing procedures for screening les for collusive activity. The congressional action requiring sealed dding also requires "adequate monitoring systems" (U.S. Laws, Statutes, etc. 76). The third issue concerning the USDA Forest Service sales program als with equity considerations in the Small Business Administration (SBA) t-Aside Program. Large firms contend that the program is biased in favor the small participating firms. Small firms have raised questions about e usefulness of the program because of the possibility that set-aside sales y cost more than open sales.

These issues can be concisely stated in three questions:

1. What was the impact of sealed bidding?
2. Can sales be screened for unusual bidding patterns?
3. Are set-aside sales typical of all timber sales?

e purpose of this paper is to first assess the concerns regarding each sue and then to identify hypotheses for evaluating arguments for and ainst each concern. Then the identified hypotheses will be tested and licy implications drawn from the results.

The existing studies on competition for Federal timber (Mead and milton 1968, Wiener 1969) provided little help in resolving these issues they were out of date. The only study using recent data was not widely ailable and pertained only to northern Idaho and Montana.[1]

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[1] Johnson, Ronald Nils. 1977. Competitive bidding for federally owned ber. Ph. D. thesis. Univ. Wash., Seattle. 175 p., illus.

This study differs from earlier studies in that sales are viewed as having quality aspects that influence how prospective bidders judge the potential profitability of a sale. Potential profitability is not the sole determinant of bidder response; other factors, such as scarcities of local raw materials may lead to responses inconsistent with perceived profitability. In this study, however, bidder activity and bid prices are generally assumed to vary directly with potential profitability. The goal of analysis then is to examine how bidders (as measured by either amount of bid or number of bidders) respond either to changes in the quality aspects or to changes in administrative variables, such as the bidding method.

This study concentrates on Regions 1, 5, and 6 (Northern, Pacific Southwest, and Pacific Northwest) which account for roughly 83 percent of the total National Forest sawtimber harvest. All analyses are conducted by appraisal zones.[2/] These zones are shown in figure 1 and will be referred to as Region 1 zone 2 (northern Idaho and Montana west of the Continental Divide), Region 6 zone 1 (eastern half of Washington and Oregon), Region 6 zone 2 (western half of Washington and Oregon), Region 5 zone 3 (northern California), Region 5 zone 1 (west Sierra area), and Region 5 zone 2 (east Sierra area).

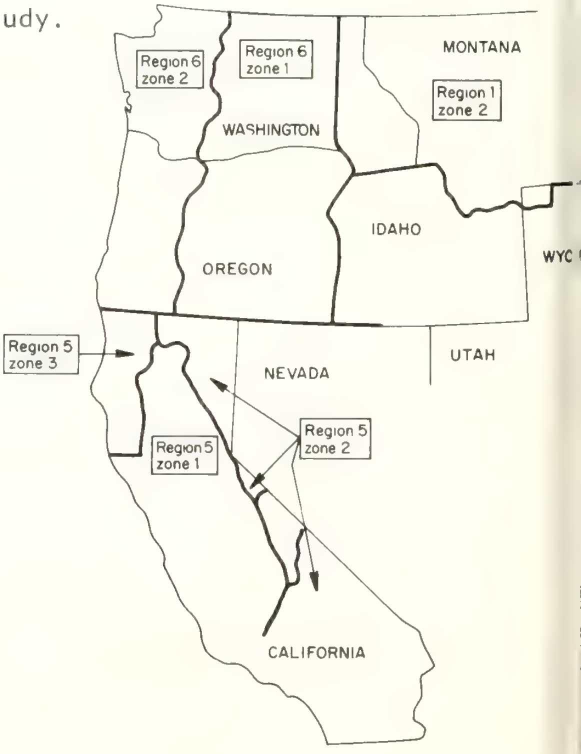

Figure 1.--Areas included in the study.

[2/] Appraisal data are developed for broad zones of similar types of tim and operating conditions. Operators in these zones are assumed to have similar cost structures and receive about the same prices for products.

The format of this paper is to discuss first the available sales data, he theory of competition, and background information on bidding practices; hen each issue and the methods used in the analysis; and last, the policy mplications as they pertain to the USDA Forest Service sales program.

efinitions and Available Data

The sale price of a National Forest timber sale will be referred to as he bid price and is expressed on a per-thousand-board-foot (Scribner) asis. The bid price for a particular sale is the weighted average price of ll species on the sale--where the weighting for each species is based on he ratio of the volume of that species to the total sale volume. In this tudy, the bid price is adjusted for road costs for which the purchasers eceive a credit. The adjusted bid price is commonly referred to as the tatistical high bid.

In the past, studies describing the state of competition for Federal imber used the bid-appraisal ratio as a measure of competition. For an ndividual sale, this is the weighted average bid price for the timber in a iven sale divided by the weighted average appraised stumpage price for the ame timber. The bid-appraisal ratio is used to classify sales as either ompetitive or noncompetitive, depending on the size of the ratio. Mead and amilton (1968) used the bid appraisal ratio to isolate token bid sales here evidence of serious bidding is lacking. They also classified sales th only one bidder as noncompetitive.

In this study, a slightly different price variable is used in classifying ales as competitive or noncompetitive. This price variable is bid price nus road costs and appraised stumpage. It will be referred to as overbid. verbid was used because it provides a cardinal measure of competition. hat is, it provides an absolute (or real) measure as well as a consistent easure. Bid appraisal ratios provide only an ordinal measure in that the ssigned value is only relative to other sales observed at the same time. his distinction is important if differential rates of inflation are ecognized in the cost and price elements leading to the appraised price nd in the premium that bidders are willing to pay for the timber on a sale.

The effects of differential rates of inflation can be illustrated by an xample. Suppose four sales were equal in size, species, and appeal to idders; one sale was offered each year; there was 10-percent inflation in he appraised price; and no inflation in overbid. The changes in major riables of interest are shown in the following tabulation:

Year	Appraised price	Overbid	Total bid	Bid-appraisal ratio
	(Dollars per thousand board feet)			
1	39.00	35.00	74.00	1.90
2	42.90	35.00	77.90	1.82
3	47.20	35.00	82.20	1.74
4	51.90	35.00	86.90	1.67

As shown, the bid-appraisal ratio declines as a result of inflationary changes in the appraised price. This decline illustrates the point implied that the bid-appraisal ratio provides only a relative measure at any point in time.

This example could have been constructed to maintain a fixed bid-appraisal ratio for each sale if overbid had been assumed to increase in real terms at the same rate as the appraised price. The choice, therefore, between overbid and bid-appraisal ratio as the better measure of competitio depends on what one assumes about differential rates of inflationary change in prices, costs, and total bid. In this study, differential rates of inflation are assumed and overbid is used as the measure of competition.

In this study, sales were defined as noncompetitive if their overbids were less than one-half of 1 percent of the average overbid for the appraisal zone in which the sale is located. For example, a sale taking plac in fiscal year 1976 would be noncompetitive in Region 6 zone 2 if the overb is less than 59 cents per thousand board feet (MBF). This definition inclu sales that would be classified as noncompetitive by the bid-appraisal ratio For example, Mead and Hamilton (1968) classified sales as noncompetitive if the bid-appraisal ratio was less than 1.01. In the case of Region 6 zone 2 the overbid corresponding to a bid appraisal ratio of 1.01 would be approximately 32 cents per thousand board feet.

The analysis of several aspects of the sealed bid issue required that each of the six appraisal zones be rated, based on the degree of competitio generally found on the timber sales in that zone. Mead (1967) used the percent of sales he classified as competitive as a measure of competition. A similar measure would be the ratio of volume sold in competitive sales to the total volume sold. The results of both Wiener's (1969) and Mead and Hamilton's (1968) studies suggest an alternative measure of competition--the difference in sale sizes between competitive and noncompetitive sales. Both studies considered Region 6 zone 2 as extremely competitive and found that for that zone noncompetitive sales were smaller than competitive sales Differences in sale size between competitive and noncompetitive sales were tested by a *t* test to determine whether the mean volume of competitive sale were equal to the mean volume of noncompetitive sales.[3] The results for all three methods are shown in the tabulation:

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[3] Significant test results require a *t* statistic of greater than 1.98 (assuming the number of observations is greater than 120). Unless otherwis specified, the 5-percent level of significance is used throughout this paper. This means that if the means are equal, the probability of obtainin significant results are only 5 percent.

Region	Zone	Percent competitive sales	Percent competitive volume	t-statistic for test of means
1	2	0.731	0.667	1.96
5	1	.840	.863	-.93
5	2	.898	.921	-.66
5	3	.876	.915	-1.21
6	1	.563	.571	-.33
6	2	.940	.974	-4.56

Region 6 zone 2 is obviously competitive; Region 1 zone 2 and Region 6 zone 1 less competitive. No clear-cut distinctions are possible in Region 5 as the percent measures indicate active competition, but the test of sale size means does not support the conclusion.

The data base for the analysis consisted of National Forest timber sale ata for fiscal years 1975 and 1976 and calendar year 1977. Complete records re available for each sale made in the National Forest System. For each ale, these records include variables identifying the sale, the physical haracteristics, the costs used in appraising the sale, and the bidders and arious bid prices. From an empirical standpoint, the sales characteristics nd cost variables are important because they measure the quality of the imber sale, and this may influence bidder activity and bid prices. A list f variables available from each sale and used in subsequent analysis ollows:

hysical characteristics:
- Volume per acre
- Volume
- Percent major species
- Percent fiber (Region 6 only)
- Haul distance

osts and prices associated with the sale:
- Appraised stumpage
- Selling value
- Logging
- Manufacturing
- Road

idder-related variables:
- Number of bidders
- Overbid (price paid minus road costs and appraised stumpage costs)
- Size class of purchaser

dministrative variables:
- Type of sale--salvage, competitive, or set-aside
- Sale method
- Region, forest, zone, district, and sale number
- Quarter and month of the sale
- Termination period

This data base will support statements made about the events during 1974-77 in Regions 1, 5, and 6 and inferences about possible events in those Regions during nonsampled years. The data base will, to some degree, support statements extrapolating the experience in the sampled Regions to other Regions. These latter statements may be subject to considerable error, depending on the sale characteristics in the Regions in question.

Some of the data listed were either computed or summarized from data appearing in the sale records (which are abbreviated facsimiles of the standard sales form 2400-17). The volume-per-acre variable, for example, i computed by dividing total sale volume by the reported sale acreage. In many cases, the reported acreage includes both the area of timber cut plus uncut acreage, buffer strips, etc. This results in per-acre figures that are biased downward, but the bias should be uniform within a given appraisa zone since all sales are appraised by common methods. The major species variable measures the percent of the total sale volume accounted for by a specified species. The specified species varies by appraisal zone as shown in this tabulation:

	Zone		
Region	1	2	3
1		Douglas-fir	
5	Pine (except lodgepole)	White fir	Douglas-fir
6	Pine (except lodgepole)	Douglas-fir	

The measure for fiber is the percent of total sale sawtimber not suitable for grades 1, 2, or 3 saw logs, including undersize material, hardwoods, and dead and down material. Cost and price variables are volume-weighted averages for each sale and are expressed on the basis of per thousand board measure, Scribner scale. The number-of-bidders variable includes all bidde who qualified to bid. Other measures of number of bidders were tried, such as number of active bidders, but these measures proved to be highly correlated. The size class of the purchaser refers to whether the purchaser is a small business (less than 500 employees) or a large business. Other variables need no explanation.

Two types of sales were deleted from the analysis. First, all sales taking place within sustained yield units were deleted. The timber sales o these units either go to a specific firm at the appraised price or are sold in open competition to firms who will process the timber within the unit. In either case, the sales do not reflect a freely operating market.

There are several of these areas in the West, and the largest involved 127.5 million feet of timber in 1977. The second type of sales deleted was those that had no bidders. These sales were deleted to avoid counting them twice as many of these sales are readvertised and sold.

I deflated all cost and price data by the appropriate value of the wholesale price index--all commodities (1967=100) to offset the different rates of inflation in each quarter of the period covered by the data. Admittedly, deflating by the wholesale price index does not account for all the inflation or variability in prices or costs. Deflating does, however, make comparison of temporally distinct periods and aggregation over broad periods more compatible.

After deflation, the values reported in this study should be interpreted as the value expressed in 1967 dollars (the base year of the index). Further, changes between two points in time should be interpreted as a real change since inflationary increases have been factored out. The values could be converted to the original form by multiplying the value by the appropriate monthly wholesale price index (all commodities).

The period July 1974 through December 1977 is perhaps not typical of the post-World War II period in regard to price swings in forest product markets. More important, however, this period is not very different from the past decade. These words of caution should not be interpreted to mean that the study will lead to atypical results. Since the appraisal system follows the wholesale lumber price index, appraised price has moved up and down (as shown in figure 2) so that the effect on how bidders respond to sale characteristics is largely unaffected.

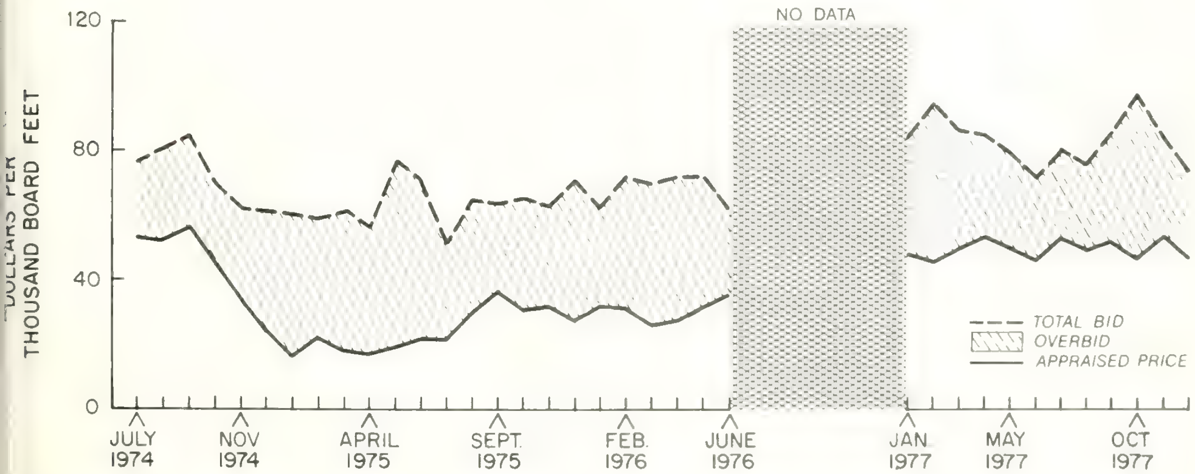

Figure 2.--Appraised price, overbid, and total bid in Region 6 zone 2.

ECONOMIC THEORY AND TIMBER MARKETS

Stumpage markets are frequently assumed to be competitive; that is, buyers and sellers interact to establish prices that reflect the underlyin supply and demand forces. Mead (1966), however, has argued that markets f Federal timber are largely oligopolistic (characterized by a small number participants) and may lead to markets that diverge from the competitive market model most frequently used by economists. Irland (1976), on the other hand, has argued that forest products markets are workably competiti with low buyer concentration, responsive competitive pricing, and an absen of supranormal profits.

A brief introduction to how markets for Federal timber compare with t competitive market model may help in understanding opposing viewpoints on the competitiveness of National Forest timber sales. Throughout this stud competitive stumpage markets are assumed. A competitive market model assu that neither the buyer nor the seller can influence price through the size of their purchases or sales. The most important criterion for determining competitive market has traditionally been multiplicity of traders (Stigler 1966), but the possibility that a number of traders might collude has led other conditions. These conditions are perfect knowledge, product homogeneity, and product divisibility.

Both Mead (1966) and Irland (1976) recognize that the number of parti pants in Federal timber markets are limited by the spatial dispersion of t resources and the forest products industry. In some areas, this may lead stumpage markets that are divergent from the competitive norm. Domination by a single firm in a particular location, however, is offset by the heter geneity of the firms bidding on the timber. These firms differ in size, product lines, and cost structures. Another factor that may tend to count act one firm's dominating any particular market is the heterogeneous natur of timber sales. Many firms are equipped to handle certain species and grades, and there is little benefit in purchasing sales not having the species or grades needed.

On the other hand, some firms may pursue a preclusive bidding strateg to prevent certain firms from becoming established in an area. Since ther are no restrictions (except those regarding log exports or the Set Aside Program) on subsequent sales of unwanted species and grades, a firm could buy a sale for which it has few or no plans for processing and sell the lo on the open market. In that way, one firm could control who gets the logs but not necessarily the price paid for the logs.

One might expect sellers of stumpage, in many areas only the USDA Fore Service, to exercise considerable power to deviate from the competitive norm. For practical purposes, the USDA Forest Service seems to exercise little market power, having diminished its potential strength through an appraisal system oriented toward fair market values, open bidding, and by offering a wide spectrum of timber sizes and quality.

The first of Stigler's (1966) additional conditions deals with the xtent of available information, which in the case of National Forest timber ales is considerable. The USDA Forest Service makes available to each nterested bidder a complete description of the sale, including the appraisal of the net stumpage price. In addition, the oral bidding methods sed by the USDA Forest Service in the West allows for instantaneous adjustent in assessing how other firms value a particular sale. Although data xist showing how firms have bid in the past and data exist for uncut olumes under contract by each firm, few firms seem to make use of the nformation. Nevertheless, the competitive market model requires only the vailability of relatively complete information and does not make any ssumptions about how it is used by individual firms.

The second condition is product homogeneity, which in forestry is easured within species, log grades, and size classes and between different andowners. The USDA Forest Service generally sells the same species and rades of logs as are available from other sources. Forest products are haracterized by a high level of product homogeneity as the bulk of forest ndustry output is concentrated in commodity grade items and sold under ndustrywide grading standards. Perhaps the only distinction some National orest sales might enjoy is a higher volume of old growth, which might ommand a slight premium in some uses.

The concern about product divisibility (the third condition) complements e concern about product homogeneity. It is not enough to just have inividual units that are highly substitutable for one another, but each unit st also be divisible. National Forest timber sales certainly meet this ndition. Once sold, a timber sale consists of a number of logs, each of ich can be either processed by the firm purchasing the sale or sold to her firms.

Another characteristic of timber markets that can influence competition s the suitability of various disposal policies for the market conditions countered in forest products markets. Most National Forest timber is sold n open auctions by either oral or sealed bidding procedures. Oral auctions ave both good and bad aspects from an economic standpoint. On the good de, they have the potential to lower the buyer's cost of preparing a bid nce buyers can adjust bids as information is gained during the bidding ocess. The negative aspects largely involve the potential for collusive tivity, which would lead to lower prices and misallocation of resources. me economists assume that these negative aspects could be minimized by ing sealed bidding rather than oral auctions. Sealed bidding has also en proposed as a deterrent to preclusive bidding (Mead 1967).

BACKGROUND INFORMATION ABOUT BIDDING

A factor that has probably influenced expectations about bidder behavior has been that most of the past empirical studies have dealt only with Region 6 zone 2, which appears to be generally atypical when compared with the other appraisal zones included in this study. This points out th need for caution in extrapolating the results discussed throughout this report to appraisal zones not covered in the report.

This section presents a discussion of a number of relationships descr how bidders might respond to variables, such as volume and other physical sale characteristics, costs, and administrative characteristics. In this study, these relationships were used to form expectations of how bidders might respond to changes in the USDA Forest Service timber sales program, such as the introduction of sealed bidding. Three relationships are discussed in this section: the mutual relationships between overbid and othe sales characteristics, the effect of sale size on major sale characteristi and the differences between competitive and noncompetitive sales.

The numerical results for analyses of the sale size and competitive a noncompetitive sales are given in appendix 1, tables 8-19.

The Measurement of Competition

In the introduction, overbid was assumed to provide a more rigorous measure of competition than bid-appraisal ratio for National Forest timber sales. The choice was based on how inflationary cost and price increases might affect the appraised price. The basic assumption was that there wer no inflationary increases in overbid in the period covered by the data. In this section, the hypothesis that there were no real increases in overbid tested for Region 6 zone 2. Since all data are deflated, we are concerned only with the relative real increases in the various variables. Region 6 zone 2 was chosen because of the large number of sales that take place throughout the year.

Monthly averages for Region 6 zone 2 were computed from the data for appraised price and overbid. Total bid was then computed as the sum of appraised stumpage and overbid. The test of the hypothesis required estimates of real increases over time. These increases were estimated by itting the various variables as a function of time and using a semi-ogarithmic functional form. The coefficient on time was then interpreted s the monthly rate of real increases.[4] The equations for appraised price, verbid, and total bid are shown in table 1.

Table 1--Estimated relationships between major sale variables and time

Variable	Equation coefficients[1]		R^2	Monthly increase
	B_1	B_2		
				Percent
ppraised price	3.2408 + (31.33)	0.0155 (3.62)	0.28	1.562
verbid	3.5517 - (46.67)	0.0005 (0.165)	0	0
otal bid	4.1429 + (105.21)	0.0067 (4.09)	.33	.668

[1] Numbers in parentheses are student *t* values.

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[4] The particular semilogarithmic form fitted was (for overbid (OB)):

$$\text{Log OB}=B_1+B_2\text{time}; \qquad (1)$$

where

log is the natural logarithm,
time is an index of months with July 1974=1,
B_1 is the intercept coefficient, and
B_2 is interpreted as $e^{(1+i)}$ where i is the monthly rate of increase.

Taking the antilog of B_2 ($B_2^{'}$), we can solve the relationship:

$$B_2^{'}=1+i; \qquad (2)$$

$$i=B_2^{'}-1; \qquad (2a)$$

where i is the monthly rate of increase in overbid. This procedure is described in more detail in Johnston (1972).

The hypothesis was accepted that the coefficient on time in the equation for overbid was statistically insignificant; that is, based on t *t* statistic the estimated coefficient of B_2 is in all likelihood equal to zero. Equations were also estimated for appraised price and total bid, a the coefficients on time were statistically significant. Since the rate increase in overbid remains unchanged, the rate of increase in total bid should be less than the rate of increase in appraised price. This contention is supported by the equations in table 1.

The lack of any consistent real price increases in overbid supports t assumption made in the introduction. The implication is that bidders did not change their real perceptions of the relationship between sale charact istics and overbid. Perhaps the rapid increases in appraised prices acted to retard changes in overbid. Regardless, bidders seem able to adjust tot bid quickly to reflect real changes in costs and product prices.

Relationship Between Overbid and Other Sale Characteristics

Expectations about bidder response can be formed by computing the mutual relationships between overbid and various sale characteristics. On way to do this is to compute correlation coefficients. These measure the degree of closeness of the linear relationship between two variables. Correlation coefficients are pure numbers without units or dimensions and lie between -1 and +1. Positive values indicate a tendency of two variables t increase together, whereas negative values indicate that large values of o variable are associated with small values of the other variable.

In terms of how bidders respond, the most useful correlation coefficients are those between overbid and the various sale characteristics. These are shown in table 2. There are no standards that describe desirabl levels for the correlation coefficients, nor is there any way to judge whet correlations between variables are real or not. Each field of investigati has its own range of coefficients. The highest coefficients, by far, are those for the relationship between overbid and number of bidders. In gene overbid declines on salvage sales, set-aside sales, or sales with a high appraised stumpage price. Overbid increases as sales become larger, have higher manufacturing costs (which is a proxy for species and log grades), and have a greater volume per acre. Correlation coefficients were compute between each possible pair of variables, and complete tables (by appraisal zone) are shown in appendix 2.

In addition to their usefulness in forming expectations, correlation coefficients play an important role in statistical analysis. The use of statistical techniques involving more than one explanatory variable assume that these variables be independent; that is, no mutual relationship exists between explanatory variables. If independent variables are highly correlated, a loss of precision may result. In practice, this assumption interpreted to mean high collinearity (correlation coefficients approachin one) should be avoided. Modest correlation between explanatory variables usually ignored since it may be due to their common relation to a third variable.

Table 2--Correlation coefficients between overbid and major sale characteristics

Sale characteristics	Region 1 Zone 2	Region 5			Region 6	
		Zone 1	Zone 2	Zone 3	Zone 1	Zone 2
Volume per acre	-0.03	0.07	0.03	0.14	0.26	0.13
Salvage status	.03	-.07	-.02	-.14	-.26	-.12
Set-aside status	.04	-.07	-.02	-.14	-.26	-.13
Volume	0	.16	.22	.02	.08	.25
Major species	-.01	.05	-.19	-.14	-.03	.11
Appraised stumpage	.13	-.06	-.23	-.11	-.04	.08
Road costs	-.12	-.04	.18	.08	0	.13
Logging costs	-.16	-.06	-.09	.17	-.18	0
Manufacturing costs	.29	.16	.24	.38	-.11	.18
Number of bidders	.60	.67	.73	.63	.62	.47
Fiber	-.12	0	-.11	.28	0	-.10
Selling value	.14	-.02	-.15	.24	-.03	.22
Competitive status	.02	-.08	-.04	-.14	-.26	-.13
Termination period	.07	.12	.02	-.15	-.07	-.02

he Influence of Sale Size

Sale size as a proxy for sale profitability affects a number of sale haracteristics, such as overbid, road costs, logging costs, number of idders, and set-aside, salvage, or competitive status. I examined these elationships using the sale data for fiscal years 1975 and 1976 stratified nto the seven sale-size classes shown in the tabulation:

Sale-size class	Volume
	(Thousand board feet)
1	0- 500
2	500- 1,000
3	1,000- 2,000
4	2,000- 5,000
5	5,000- 8,000
6	8,000-15,000
7	15,000+

Smaller sales were more closely stratified because the relationship betwee sale size and most sale characteristics has traditionally been assumed to hyperbolic. Results for the six appraisal zones are shown in tables 14-19 appendix 1.

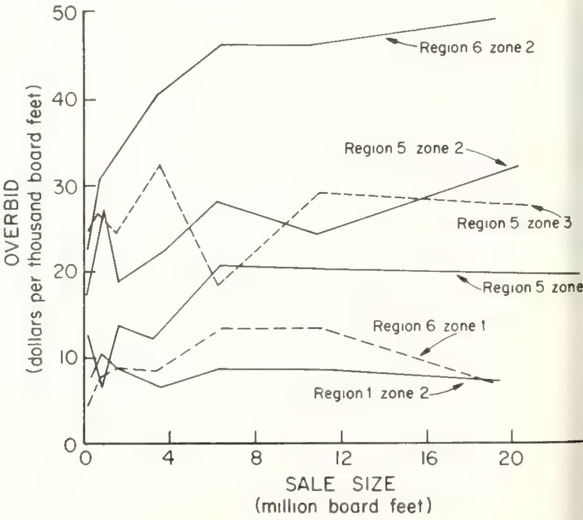
Overbid is often assumed to vary directly with sale size but at a diminishing rate. The actual relationship (for fiscal year 1975-76 data) is shown in figure 3 for the six appraisal zones. The prior statement fits Region 6 zone 2 best. For the remaining areas, overbid seems highly erratic on smaller sales. On sales over 5 million board feet, overbid seem relatively insensitive to sale size.

Road costs, like overbid, are frequently assumed to vary directly wit sale size; the fiscal year 1975-76 data support this contention. In nearl all zones, road costs per thousand board feet increase rapidly as sale siz increases until sale size exceeds 2 million board feet. Then the relationship between sale size and road costs is nearly flat. Region 6 zone 1 is the exception. There the relationship is roughly linear throughout the range of sale sizes.

Road costs have also been suggested as having a depressing influence the bid price (Ho 1963). Ho's suggestion was tested for Region 6 zone 2 using the fiscal year 1975-76 data stratified by sale size. If his suggestion is correct, then sales with low road costs should have higher overbids than sales with higher road costs.

Each sale size stratum was divided into a low and a high road cost group. The average road cost per thousand board feet for each stratum was used as the criterion for division. The average road costs per thousand

Figure 3.--Relationship of overbid and sale size.



board feet for each group and the average overbid for each group are shown in table 3. A t-test was used to compare the average overbids for each group; in general, road costs appear to have only an erratic effect on overbids. The second sale-size class is the only one in which road costs may depress overbids. If the differences in sale size are ignored, then in some zones high road costs may deter bidding in that noncompetitive sales have higher road costs.

Table 3--Data for testing the effect of road costs on overbid

Sale-size class	Average road costs	Low road costs		High road costs	
		Costs	Overbid	Costs	Overbid
	Dollars per thousand board feet				
1	0.89	0	22.03	11.84	28.78
2	1.88	.04	33.84	7.93	18.24
3	3.22	.31	33.81	11.44	29.90
4	7.51	1.95	39.57	15.97	41.93
5	10.35	5.08	48.04	18.49	42.97
6	11.13	5.24	45.19	19.70	47.99
7	10.40	5.72	50.74	17.49	45.63

Logging costs are often assumed to vary inversely with sale size in that smaller sales are expected to have high logging costs because of the initial setup costs. This is true, however, only in Region 6. In other Regions, logging costs generally increase as sales become larger and may reflect different logging systems on larger sales.

Most people have assumed that the intensity of bidding for timber sales ncreases as sale sizes get larger. When number of bidders qualifying to bid is used as a proxy for the intensity of bidding, this assumption is true. The increase in the number of bidders from the smallest to the argest sale-size class ranges from 30 percent in Region 6 zone 1 to 64 percent in Region 6 zone 2. This increase in number of bidders is eflected in the higher overbids on larger sales as these two sale characterstics vary directly with each other.

Three variables indicate how the sale will be administered. The first indicator is whether the sale is for salvage or not. As might be expected, salvage sales are concentrated in the smaller sizes and, to some extent, epress overbid and bidder participation. The second indicator is the ercent that are Small Business Administration set-aside sales. Conceptually, this program offers typical sales to qualified firms.[5] In most of the six zones studied, set-aside sales were concentrated in the 2- to 8-millio board-foot-sale size classes. In Region 6 zone 2, the program was concentrated in the 5- to 8-million-board-foot-sale class. The third indicator i competition; it will be discussed in more detail in the next section.

Competitive and Noncompetitive Sales

In terms of published studies, Mead (1966) was the first to make a practical distinction between competitive and noncompetitive sales. This latter class of sales included both one-bidder and token bid sales. Mead (1966) initially attributed noncompetitive sales to either implicit or explicit collusive practices; in a later article (1967), he proposed that industry characteristics--such as fixed investments, immobile resources, s and heterogeneity of sales, and dependency on specific resources--would le to conditions conducive to noncompetitive sales.

The emphasis in this section is on determining the characteristics of noncompetitive sale. This assumes that noncompetitive sales somehow diffe in either physical or administrative characteristics in such a way that prospective bidders evaluate those sales as being less desirable. The possibility that bidders might collude is addressed in a later section.

Each sale was classified as either competitive or noncompetitive by th criteria discussed in the section, "Definitions and Available Data." What type of sales are noncompetitive? The answer to the question varies by the relative competitiveness of each zone. In zones characterized by a relatively low degree of competition (Region 1 zone 2 and Region 6 zone 1), the is little difference in sale size between competitive and noncompetitive sales; but the noncompetitive sales are inferior in most other aspects. Th is, volume per acre and selling values are lower, but road and logging cost are higher on noncompetitive sales. In Region 5 (characterized by moderate competition), noncompetitive sales are slightly smaller than competitive sales, but the appraised stumpage price is higher on noncompetitive sales. The differences in costs and sale quality characteristics is mixed, making difficult to judge why the sales are perceived by bidders as undesirable an suggesting that perhaps other, unmeasured factors influence the bidders. I Region 6 zone 2 (characterized by intense competition), noncompetitive sale are much smaller and less attractive in that they have lower volumes per acre, higher incidence of salvage sales, and higher logging costs. Complet results are given in tables 8-13, appendix 1.

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[5] Forest Service Manual 2431.17--2. U.S. Department of Agriculture, Washington D.C.

RECENT SALES-RELATED ISSUES

The focus of the remainder of this report is the empirical examination f recent sale-related issues. These issues are the impact of sealed bidding, he type of sales being offered as set-aside sales, and the opportunity for onitoring sales. Each of the three major controversies will be examined ndependently. All analyses use the common data base described in the section, Definitions and Available Data," and all results from the various analyses re presented in appendix 1. Throughout this section, a great deal of reliance s placed on forming expectations, such as those discussed in the previous ection. The policy implications evolving from these controversies are iscussed in the last section.

he Sealed Bid Issue

During the past two decades, National Forest timber sales have used ither oral or sealed bidding procedures, depending on local preferences. he rule of local preferences was changed suddenly in the fall of 1976 when last-minute addition to the National Forest Management Act (U.S. Laws, tatutes, etc. 1976) required the use of "sealed bidding on all sales except here the Secretary [of Agriculture] determines otherwise by regulations." his mandate was a reaction to the potential for collusion on oral bidding or National Forest timber.

Proponents of oral bidding responded by arguing that sealed bidding hreatened many western communities dependent on Federal timber. Senator ackwood's description of the problem posed by universal use of sealed idding was typical. He said (Congressional Record, p. S 17278, 9/30/76):

> In many areas of Oregon there is only one lumbermill in a town. The town depends upon the mill for employment. When the mill owner knows that he is going to be short of timber, he will go out and bid to the sky, if necessary, to keep that mill going. And so long as the bidding is open, he knows how high he has to go. But when the bids are sealed, that owner may put in what he regards as a very high bid, but if for some reason somebody bids higher, that owner does not get the timber and the mill shuts down.
>
> What you end up with is a mill out of timber and a town out of jobs solely because sealed bids rather than open bids are used.

Proponents of sealed bidding cited the strong indications of collusive ractices in areas in which oral auctions have been the predominant bidding ethod. In addition, they claimed that Government income would likely ncrease if sealed bidding were required.

The debate led to congressional action in 1978, amending the National Forest Management Act to return to historical bidding methods (U.S. Laws, Statutes, etc. 1978). Key arguments of the proponents of oral bidding were community stability and the impact of nonlocal bidders.

The impact of sealed bidding on stumpage prices was an integral part o the issue over bidding practices. For example, in areas where the markets are competitive, sealed bidding was seen as having little effect on prices. Sealed bidding, however, was proposed as a means of increasing competition and prices in areas where little competition existed.

The preceding discussion introduces several questions involving sealed bidding as it affects the competition for timber:

1. Did the method of bidding influence timber prices in areas characterized by competition or by little competition?
2. Did the mix of sealed and open bidding methods in 1977 result in higher prices than those observed prior to the switch to sealed bidding?
3. Did the use of sealed bidding during 1977 lead to a higher incidence of nonlocal bidders?

The following sections present analyses of each of these questions.

THE INFLUENCE OF BIDDING METHOD ON BID PRICES

During 1977 the USDA Forest Service offered both oral and sealed bid sales. The proportions of each method varied from Forest to Forest, depending on the regulations governing the implementation of sealed bidding.[6] The two groups of sales (oral and sealed bid) were treated as two independe samples, and the differences in the means of various sale characteristics were tested (using a *t*-test) for significance.

One question which generated considerable interest was the impact of sealed bidding on stumpage prices represented here as overbid. The impact was hypothesized to differ between competitive and noncompetitive areas.

In competitive areas, no difference in overbid was expected between bidding methods. In noncompetitive areas, a significant difference was expected between bidding methods. The results, in general, did not support the hypotheses. Region 6 zone 2 was the only Region in which sealed bidding resulted in a significant difference in overbid, and this was contrary to what was expected since this zone is competitive. The differences in overbid per thousand board feet are shown in the tabulation:

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[6] These regulations were given in the Federal Register (1977).

	Appraisal zone		
Region	1	2	3
	(Dollars)		
1	--	2.01	--
5	-15.40	11.79	-25.23
6	.82	7.64	--

e minus signs indicate that, on the average, overbids on oral auction les were higher than on sealed bids. Complete results are given in bles 20-25, appendix 1.

The incongruous nature of these results can be better understood examining the differences in sale size between oral and sealed bids. e differences are shown in the tabulation:

	Zone		
Region	1	2	3
	(Thousand board feet)		
1	--	-3,568	--
5	-8,133	-1,928	-10,628
6	-1,631	-918	--

n every zone, oral sales are larger on the average than those offered nder sealed bidding. This suggests that differences in sale size may istort comparisons of overbid for sealed bid vs. oral auction sales.

To improve the sensitivity of the analysis, I stratified the data by ale size into three groups: 0-2, 2-8, and 8+ million board feet. This is ughly the same procedure Johnson used when he split sales into two roups based on road costs (see footnote 1). He argued that sealed idding would produce higher prices on sales where the bidders had ifferent cost structures. Sales with higher road costs would attract arger and more efficient bidders who could afford to pay more for a ale. In this analysis, sealed bidding is expected to have a greater npact on larger sales since road costs vary directly with sale size.

When we consider the effects of sale size and testing, the two sealed bid hypotheses lead to the results shown in table 4. Complete results are given in tables 26-42, appendix 1. Sealed bidding resulted in higher overbids on sales between 2 million and 8 million board feet in both zones characterized by little competition. This is the most common sale size, and the results for Region 1 zone 2 support Johnson's finding for the same area (see footnote 1). In addition, sealed bidding led to higher overbids on the smallest and largest sales in Region 6 zone 2. These results were not expected in Region 6 zone 2 and suggest that if the degree of competition for each Region had been assigned by sale size, the resulting classification would have been different for the smaller sales in Region 6 zone 2. Elsewhere, sealed bidding led to higher overbids, but the results were not statistically significant.

Table 4--Differences in overbid per thousand board feet by sale size[1]

Region	Zone 1, by sale size			Zone 2, by sale size			Zone 3, by sale size		
	1	2	3	1	2	3	1	2	3
1				+1.11	+5.76	+5.03			
5	+2.45	-16.38	+6.88	-4.69	+29.58	+33.39	--	-16.85	+3.47
6	-2.03	+8.67	-1.44	+12.70	+2.27	+9.33			

[1] The plus sign or minus sign signifies whether the overbid on sealed bid sales was greater than or less than the overbid on oral bid sales. Sale size 1 is 0-2 million board feet; sale size 2 is 2-8 million board feet; sale size 3 is 8+ million board feet.

HISTORICAL BIDDING PATTERNS VERSUS A MIX OF ORAL AND SEALED BIDDING METHODS

The USDA Forest Service did not universally adopt sealed bidding but rather implemented a mix of bidding methods in 1977, raising the question of whether the mix of bidding methods led to higher overbids. This question is formalized in the following hypothesis. The mix of bidding methods used in 1977 resulted in higher overbids than the mix of bidding methods prevalent before the congressional action--U.S. Laws, Statutes, etc. (1976).

The hypothesis was tested by determining if the introduction of a large number of sealed bids caused a shift in the relationship between overbid and sale characteristics and between overbid and bidder behavior. That relationship can be expressed as

$$y = c_1+c_2Z+c_3B; \tag{3}$$

where

y is the overbid,
Z is the sale characteristics,[7]
B is the number of bidders, and
C_i is the coefficient for the i^{th} variable.

The estimation of this relationship is complicated by seemingly erratic movements in forest product prices and costs even though they have been deflated by the wholesale price index. Figure 2 illustrates how the overbid for Region 6 zone 2 varied during the 3-year period included in this study. A monthly time trend was added to the model to further explain the shift in prices over time. This time trend is a sequential index of the month and year that the sale occurred.

A technique developed by Chow (1960) and later described by Johnston (1972) was used to test the hypothesis that the 1977 mix of bidding methods resulted in higher overbids than the mix of bidding methods prevalent before. Essentially, the test involves fitting a regression to the observations in the first period (fiscal years 1975 and 1976) and then pooling the data from the first period with the data from the second period (calendar year 1977) and estimating a second regression relationship from the combined data set. The test statistic is then a ratio of the residual sum of squares[8] from the two estimated relationships. Test results for the six appraisal zones are shown in appendix 3; they led to the rejection of the hypothesis that the relationship between overbid and both sale and bidder characteristics shifted between the base period and calendar year 1977.

THE OUTSIDER QUESTION

The introduction of sealed bidding threatened to limit the effectiveness of established firms in an area controlling access of new or outside firms (those whose processing facilities are located outside the local community) to localized timber markets. Thus, the arguments against sealed bidding revolved around the probable impact of outside bidders and were often stated in conjunction with concerns about community stability. The scenario often described was that outside bidders could materially affect a community which was dependent on the local forest products industry for employment if that industry was dependent on public timber as a raw material source.

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[7] Includes both physical and cost characteristics listed on page 5.

[8] In this case, the residual sum of squares measures the portion of he overall dispersion of observed overbids not explained by the estimated ines of regression.

Opponents of sealed bidding argued that outsiders are more of a problem under sealed bidding. All 19 National Forests in Region 6 were surveyed to investigate this possibility. The survey covered the base period (fiscal years 1975 and 1976) when oral auctions were the prevalent sales method and the first 9 months of 1977 when sealed bidding was common. Each bidder on each sale was classified as either an expected bidder or an unexpected bidder (an outsider); whether the primary manufacturing facilities of each bidder were located within the adjacent dependent community was also determined.[9]

The outsider data base was used to test the hypothesis that the incidence of outside bidders remained either unchanged between the two periods or the mean of the second period was less than the first. The alternative hypothesis was that the incidence of outsiders was higher in the second period (characterized by sealed bidding). The analysis was conducted by computing for each Forest and for each time period the average number of outsiders on each sale.

Across the Region, sealed bidding did not lead to a higher incidence of outsiders, as the regionwide average of 0.4 outsider on each sale was roughly the same in the base period and in 1977. As might be expected, this regionwide average varies widely between individual Forests and may be related more to timber supply than sale method. Forests in Region 6 zone 1 generally have a higher incidence of outsiders than the Forests in Region 6 zone 2 (table 5).

A *t* test was used on the hypothesis concerning differences between the average number of outside bidders in each period for each Forest and appraisal zone. The hypothesis was rejected only in Region 6 zone 2 where the average number of outsiders on each sale increased from 0.29 to 0.35. The first hypothesis was not rejected in Region 6 zone 1 or in the Region as a whole. For individual Forests, there were significant differences in seven Forests. Of the seven, three Forests (Wenatchee, Mount Baker-Snoqualmie and Gifford Pinchot) experienced a decline between the base period and 1977. This decline was inconsistent with the general expectation that sealed bidding leads to greater opportunities for outsiders. Three Forests in southwest Oregon experienced an increase in outsiders as did the Ochoco National Forest in zone 1.

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[9] Federal Register (1977) definition: "'Adjacent dependent community' means an area with common social and economic interests bounded by established daily marketing and workforce connecting patterns, and encompassing one or more primary wood product manufacturing facilities located within or adjacent to a specific area of National Forest timber upon which it is dependent for its timber supply and where 10 percent or more of the community workforce is employed in the primary manufacture of wood products, including logging and log transportation, and National Forest timber accounted for at least 30 percent of the timber used in the primary wood product manufacturing facilities in the last 5 calendar years."

Table 5--Average number of outsiders bidding on sales in Region 6

National Forest and zone	1975-76[1]		1977[2]	
	Average	Standard deviation	Average	Standard deviation
Deschutes	0.653	1.958	0.576	0.902
Fremont	1.070	.961	.615	.506
Malheur	.047	.213	.083	.280
Ochoco	.231	.583	.667	.492
Okanogan	.571	.870	.417	.793
Umatilla	1.172	1.037	1.020	1.005
Wallowa-Whitman	.064	.247	.091	.292
Wenatchee	.638	.965	.143	.359
Winema	.326	.845	.333	.485
Colville	.333	.479	.267	.704
Region 6 zone 1	.510	1.055	.421	.381
Gifford Pinchot	.296	.683	.093	.336
Mount Baker-Snoqualmie	.199	.493	.087	.284
Mount Hood	.313	.590	.219	.417
Olympic	.457	.919	.222	.548
Rogue River	.301	.652	.681	1.163
Siskiyou	.447	.701	.557	.723
Siuslaw	.549	.886	.842	.960
Umpqua	.040	.195	.482	.817
Willamette	--	--	--	--
Region 6 zone 2	.291	.563	.354	.380
Region 6	.406	.709	.389	.616

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[1] Oral bidding was the predominant sale method.

[2] Sealed bidding and oral bidding were both used.

In southern Oregon, as well as other areas, some outsiders were ctually firms located within the adjacent dependent community but they ad not bid previously on sales in the area.

The impact of outsiders is commonly thought of as increasing bid rices as local bidders attempt to prevent entry of outsiders into an rea or as the outside bidder pays an excessive premium to gain entry. he impact of outsiders on bid prices can be examined by combining he outsider data base with the sale data used in the other analyses nd then testing the hypothesis that the presence of outsiders led to ore intense bidding and higher overbids.

The results for Region 6 zones 1 and 2 are given in appendix 1, tables 43 and 44. The hypothesis was accepted in both zones as the presence of outsiders led to a greater number of bidders and higher overbids ($7.39 per thousand board feet greater in zone 1 and $8.37 per thousand board feet greater in zone 2). The difference in overbids raises the question that possible differences in the physical characteristics of the sales themselves might have accounted for the different overbids. In zone 1, the sales that attracted outsiders were on the average nearly 1 million feet larger than those attracting only expected bidders. Other than that distinction, there was no difference between sales attracting outside bidders and sales attracting only expected bidders. In both zones, set-aside sales attracted a higher number of outside bidders than did open sales.

The SBA Issue

The SBA Set-Aside Program is designed to provide opportunities for small forest product firms to remain viable. The purpose of the program is to help insure that a predetermined share of National Forest timber harvest is available to qualified small forest products firms. To qualify, firms must be primarily engaged in logging or the manufacture of forest products, must be independently owned and operated, must not dominate in their field of operation, and must not employ more than 500 employees (see footnote 5).

Briefly, the intent of the Small Business Set-Aside Program is to "aid, counsel, assist, and protect insofar as possible the interests of small business concerns in order to preserve free competitive enterprise." (U.S. Laws, Statutes, etc. 1958). The program is activated when small business firms are unable to purchase a predetermined percentage of the volume offered. This percentage is based on buying patterns over a 5-year period. For example, the current average small business share of the sawtimber volume offered in Washington and Oregon is 51 percent.[10/]

If small business firms do not purchase their share of sales during a 12-month period and the accumulated deficit is greater than 10 percent of the small business share for the period, a set-aside program is triggered for the following 12 months. During the first 6 months of this subsequent period, sales containing enough total volume to equal approximately half the accumulated deficit plus the small business share for the period are offered as set-aside sales restricted to qualified small business firms. During the second 6-month period, any remaining deficit volume plus the small business

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[10/] In the two States, the SBA share is computed for 34 market areas and ranges from 6 to 92 percent.

share are offered as set-aside sales. These sales may be purchased by large firms only if the USDA Forest Service receives no bids from qualified small firms and if the sale is readvertised.

A concern involving the USDA Forest Service timber sale program has been whether large and small bidders are being treated equitably by the Small Business Set-Aside Program; that is, during the period covered by the data, did the characteristics of sales offered as set-aside roughly equal those offered for open bidding and were bid prices equal. In this section National Forest sale data were used in examining these concerns for the six appraisal zones.

Regulations (see footnote 5) provide two guidelines for the selection of set-aside sales. First, consideration should be given to the type of material needed by small businesses and the capability of the small businesses to operate the sales. Second, sales in the Set-Aside Program should be typical of sales currently offered on the Forest. In practice, the sale selection process may focus more on providing material suitable for small firms than on insuring that the two classes of sales are similar. For example, the USDA Forest Service has been reluctant to designate as set-aside sales either sales involving helicopter yarding or salvage sales containing large amounts of chippable material. In the latter case, few small firms can utilize the material as it is best suited to the manufacture of pulp and paper and these facilities are invariably only available in large businesses.

Three aspects of the sale selection process can be expressed as hypotheses suitable for statistical analysis of National Forest sales data. These hypotheses are:

1. No difference exists between the characteristics of set-aside and open sales.
2. Logging costs are less on set-aside sales than on open sales.
3. The volume of chippable material is less on set-aside sales than on open sales.

The test of the first hypothesis indicates whether the characteristics of set-aside sales are typical of open sales. The tests of the next two hypotheses indicate the extent to which the Set-Aside Program takes into account the capabilities of small businesses to operate sales and to use the material on each sale.

The second issue deals with bid prices. One would expect that if the characteristics of the two types of sales are similar, there would be no difference in the bid prices or number of bidders. This led to a fourth hypothesis: No difference exists between the overbids of set-aside and open sales.

Testing the hypotheses involved collecting similar data for each sale. A combination of all sale characteristics (listed in appendix 1, tables 45-50) was used to test the first hypothesis. A single variable was used to test the second, third, and fourth hypotheses. Logging costs were chosen for the second hypothesis as these costs vary, depending on the required logging techniques. The assumption is that less expensive techniques would be encountered more frequently on sales purchased by small firms. The third hypothesis was tested only in Region 6 zone 2; the percentage of total volume classified as PAM (per acre material) was used as the measure of chippable volume. The fourth hypothesis used high bid minus appraisal stumpage and road costs as a measure of bid prices.

The first hypothesis was tested by comparing the linear combination of corresponding characteristics between open sales and set-aside sales. The values for competitive status, number of bidders, and bid price are only for information and were not used in testing the hypothesis. In all Regions, except Region 5 zone 3, the null hypothesis was rejected because the linear combination of means differed between the two types of sales. Discriminant analysis was used as a multivariate generalization of the $\underline{t}$ test to test the first hypothesis. Details are given in appendix 4.

The second, third, and fourth hypotheses were tested by pooling the variance of the characteristic under consideration for both set-aside and open sales. The means were then compared with a student's $\underline{t}$ test for the two types of sales. A summary of the differences in means is given in table 6. The second hypothesis stated that logging costs are less on set-aside sales than on open sales, and the analysis indicated that a statistical difference does exist in both zones in Region 6. In other zones, logging costs on set-aside sales were roughly the same as on open sales. For Region 6 zone 2, the third hypothesis that the volume of PAM material on set-aside sales was less was rejected. Although on the average there was slightly less PAM on set-aside sales (0.53 percent), this difference was not statistically significant.

The fourth hypothesis stated that no difference exists between the overbids of the two types of sales. The differences in overbids are shown in table 6. The hypothesis was rejected (at the 5-percent level of significance) only in Region 6 zones 1 and 2. In Region 6 zone 1, set-aside sales had significantly larger overbids than did open sales. In Region 6 zone 2, set-aside sales had significantly lower overbids than did open sales; these results were unexpected since set-aside sales there are significantly larger and would be judged as having higher potential profitability. This was also true, but to a lesser extent, in Region 1 zone 2 and Region 5 zone 2.

Table 6--Differences in means between set-aside and open sales[1]

Region	Zone	Sale size	Overbid	Logging cost	Road costs
		Thousand board feet	Dollars per thousand board feet		Dollars
1	2	291	[2]-2.89	0.86	[3]3.44
5	1	401	5.07	.48	[3]4.68
	2	2,670	[2]-7.97	-4.70	[3]2.94
	3	[2]3,028	1.83	-.43	3.42
6	1	472	[3]3.68	[2]-2.06	[3]1.54
	2	[3]1,539	[3]-5.78	[3]-1.79	[3]2.55

[1] A minus sign denotes higher value on open sales than on set-aside sales.

[2] Significant at the 90-percent level.

[3] Significant at the 95-percent level.

This analysis was extended by separating the open sales purchased by small firms from open sales purchased by large firms and making two comparisons. The first comparison was whether small firms and large firms pay the same overbid for National Forest timber. The second comparison was whether there was a difference in overbid between set-aside sales and open sales purchased by small firms. The results for each of the three groups by appraisal zone are given in tables 51-56 in appendix 1.

These comparisons were made by analysis of variance techniques. A linear combination of the group means was formed for each comparison, each mean multiplied by a number (see Snedecor and Cochran (1967) for details). In the first comparison the numbers were 0.5, 0.5, and -1, respectively. These numbers were interpreted as comparing the average of the two groups of sales purchased by small firms with the group of sales purchased by large firms (the numbers must sum to zero). In the second comparison, the numbers were 1, -1, and 0. Zero was used for the third group since it was not involved in the comparison. The results are shown in table 7. The first comparison (between overbid paid by large and small firms) shows that small firms paid a smaller overbid than did large firms. The exceptions were in Region 5 zone 1 and Region 6 zone 1, where small firms tended to pay more although the differences were not statistically significant. In the other appraisal zones (except Region 5 zone 3), small firms pay significantly less than large firms. That difference should be not unexpected as the sales purchased by small firms are, on the average, 2.23 million board feet smaller in all zones than sales purchased by large firms.

Table 7--Comparisons of overbid between small and large firms and between set-aside sales and open sales purchased by small firms[1]

Region	Zone	First comparison			Second comparison		
		L[2]	SE[3]	t[4]	L[2]	SE[3]	t[4]
1	2	-2.34	1.13	2.07	2.09	1.73	1.21
5	1	4.29	3.01	1.43	3.35	5.00	.67
	2	-11.45	3.92	2.92	.79	5.62	.14
	3	-6.25	4.16	1.50	7.95	6.56	1.21
6	1	1.47	1.43	1.03	4.06	2.10	1.93
	2	-8.05	1.77	4.55	2.36	2.28	1.04

[1] The plus or minus sign signifies whether the overbid on set-aside sales was greater than or less than the overbid on open sales.

[2] Linear combination of means ($\overline{x}_i$) computed as

$$L = \sum_{i=1}^{k} \lambda_i \overline{x}_i;$$

where: λ_i are fixed numbers 0.5, 0.5, and -1 in the 1st comparison and 1, -1, and 0 in the 2d comparison.
k is the number of groups.

[3] Standard error computed as

$$SE = \sqrt{\text{within mean square} * \sum_{i=1}^{k} \frac{\lambda_i^2}{n_i}};$$

where n_1 is the sample size.

[4] Student's t ratio values in excess of 1.96 are significant; i.e., the difference in means is 95 percent certain.

The second comparison was between set-aside sales and open sales purchased by small firms. All appraisal zones shared the same results. There was no difference in the overbids between the two types of sales. These results are unexpected given the differences between the characteristics of the two types of sales. Open sales purchased by small firms are smaller in every appraisal zone, except Region 5 zone 1, than either set-aside sales or open sales purchased by large firms. They also contain the highest proportion of salvage sales. These attributes should have resulted in lower overbids for open sales than for set aside sales. The finding of no difference in overbids supports the contention put forth in the set-aside open sale analysis that overbids on set-aside sales are generally less than might be expected.

The Sale Monitoring Issue

The possibility of collusion among bidders has been of concern to some government agencies, as well as to members of Congress. The key point is how to determine whether sales that were noncompetitive might have been so because of collusive practices.

This section outlines one approach for identifying suspicious sales; that is, sales in which collusion is suspected. The approach involves separating the noncompetitive sales into two groups. The first group includes sales that prospective bidders would generally evaluate as undesirable because of low potential profitability. Little competition would be expected on these sales. The second group contains sales that have many of the attributes of competitive sales but, nevertheless, when sold, were noncompetitive. This latter group could be further studied for suspicious bidding patterns.

The first step in implementing this approach is to classify each sale as competitive or noncompetitive by the definition discussed in the section, "Definitions and Available Data." Details on how discriminant analysis is used to classify sales and the discriminant functions estimated for each appraisal zone are given in appendix 5.

The concern in sale monitoring is with sales that were a priori classified as noncompetitive. These sales are reclassified, and two groups emerge. First, there are sales for which the subsequent classification is the same as the a priori classification. These sales, for my purposes, are sales that appear to have a low potential profitability to prospective bidders. It is the second group that is of interest--it contains sales for which subsequent reclassification was different from the a priori classification. These latter sales were reclassified as competitive because they are physically similar to competitive sales. From the viewpoint of sale monitoring, these latter sales should be examined for patterns in bidding. For example, if several sales on a district are initially classified as noncompetitive but subsequently are reclassified as competitive and if the same bidders are involved, those sales should be examined for any mitigating circumstances that might account for what appeared to be collusion.

This approach was applied to the data for fiscal years 1975 and 1976. The power of the approach was greatly diminished by use of discriminant functions estimated for each appraisal zone rather than estimating functions on a more specific scale. Nevertheless, the possibilities of the approach can be explored through an example.

The example was identified by reclassifying the noncompetitive sales to determine if any had the characteristics of competitive sales. Several potential examples emerged, and the following was selected: All four initially classified noncompetitive sales within one district in Region 5 were reclassified as competitive. Only one of the five sales offered in the district had been competitive in the 2 years covered by the data and that sale comprised only 1 percent of the volume sold. Closer examination revealed that the same four bidders always bid on the noncompetitive sales but did not bid on the one competitive sale that took place during the period.

The example illustrates the ability of discriminant analysis to separate suspicious bidding patterns from the larger set of noncompetitive sales. The analysis in this study indicated that most noncompetitive sales are such because they appear to bidders to have low potential profitability. The example used here illustrates a bidding pattern that might involve collusive practices. On the other hand, this bidding pattern may have arisen out of chance, or mitigating circumstances may explain it.

Summary

In this section, 10 hypotheses were tested for related timber sale issues. No hypotheses were tested for sale monitoring--the third sales-related issue. An example was used instead to illustrate how sales could be monitored.

The 10 hypotheses are summarized on the following page:

Hypothesis	Comments
In competitive areas there is no difference in overbid, between oral and sealed bidding methods, but in noncompetitive areas there is a significant difference.	Results did not support the hypothesis.
The first hypothesis was repeated for three sale sizes (0-2, 2-8, and 8+ million board feet).	Sealed bidding led to higher overbids on sales between 2 and 8 million board feet in areas characterized by little competition.
The mix of bidding methods used in 1977 resulted in higher overbids than the mix of bidding methods used in the 1975-76 period.	Results did not support the hypothesis.
Incidence of outside bidders remained unchanged over the 3-year period (Tested only in Region 6).	Regionwide, the data supported the hypothesis. The incidence of outsiders, however, has increased in Region 6 zone 2.
Where the incidence of outsiders has changed it was higher under sealed bidding (Tested only in Region 6).	The incidence of outsiders was higher in Region 6 zone 2.
The presence of outside bidders on a sale leads to higher overbids (Tested only in Region 6).	Overbids in both zones of Region 6 were higher on sales where outsiders participated.
No difference exists between characteristics of set-aside and open sales.	The hypothesis was rejected.
Logging costs are less on set-aside sales.	The hypothesis was accepted only in Region 6.
Volume of chippable material is less on set-aside sales (Tested only in Region 6).	The hypothesis was rejected.
No difference exists between the overbids of set-aside and open sales.	The hypothesis was accepted only in Region 5 zones 1 and 3. In Region 6 zone 2, Region 1 zone 1, and Region 5 zone 2, overbids on set-aside sales were significantly less than the overbids on open sales. In Region 6 zone 1, overbids were higher on set-aside sales than on open sales.

POLICY IMPLICATIONS

The empirical analysis of sale characteristics for the three issues illustrates that the impact of various sales-oriented programs is highly variable when actually applied. Given this variation, there is little reason to expect that sales offered as either oral or sealed, open or set-aside would be of roughly equal size and potential profitability and have the same bid price.

Given the physical differences in sales, the salient policy question i whether bid prices match expectations based on sale size and profitability. Lower prices for sales of at least equal profitability is symptomatic of either restricted competition or a lack of competition. This may be the case in some areas for the Set-Aside Program which limits participation to small firms.[11] In the case of sealed bidding, the USDA Forest Service may have inadvertently limited the effectiveness of sealed bidding in increasin competition and bid prices by the regulations governing its use. For example, in some areas, oral auction sales tended to be of better quality than sealed bid sales.

Sealed Bidding

In general, sealed bidding did not lead to uniformly higher bid prices. There may be reasons for this conclusion, however, that are not readily apparent. For example, sealed bid sales are generally smaller than oral auction sales. This difference is influenced by USDA Forest Service regulations, which require oral bidding on any sale that, by its size, comprises more than 20 percent of the sale programs for a particular Forest. The use of oral bidding during 1977 was particularly prevalent in Region 5, which historically has had larger sales than either Region 1 or Region 6. Selling value (the single best indicator of quality) is generally lower on sealed bid sales, indicating that these sales may be of lower quality and hence should have lower prices.

Another example of regulations influencing the effect of sealed bidding in raising prices is the case of outsiders. Regulations dictate that if an outsider buys a sale, oral bidding will be used for the next 6 months. This regulation was used in Region 6 zone 1 on several Forests in 1977.

In spite of the limitations imposed by regulations, the use of sealed bidding enhanced competition for National Forest timber in the two areas (Region 1 zone 2 and Region 6 zone 1) that have historically experienced relatively limited competition. In areas where competition is strong, sealed bidding had little impact except on smaller sales in Region 6 zone 2 where sealed bidding led to higher prices.

The mix of oral and sealed bidding implemented in 1977 had little impact on overbid compared with preceding years. One reason for this was the regulations designed to minimize the impact of potential log flow shifts on timber-dependent communities. The use of sealed bidding did lead to a higher incidence of outsiders in southwestern Oregon.

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[11] This is not the same as limiting the number of bidders. Set-aside sales, in fact, generally attract a greater number of bidders than open sales do.

The Set-Aside Program

The lower prices in some appraisal zones associated with set-aside sales suggest that the Federal Government is making an implicit payment to firms winning set-aside sales. In other zones, prices for set-aside sales are higher than open sales, representing an implicit payment to the Government. The magnitude of these payments can be estimated by comparing the overbids on the two types of sales after adjusting for differences in sale size.

This adjustment involves estimating a linear function, linking overbid to sale size, and then predicting the overbids associated with each size sale. The difference in predicted overbid between set-aside and open sales was used to adjust the observed difference between the two types of sales. In Region 6 zone 2, for example, the overbid on open sales is $5.78 per thousand board feet higher than the overbid on set-aside sales, but set-aside sales average 1.539 million board feet larger. The adjustment for the difference in sale size is $2.84 per thousand board feet, increasing the difference in overbid to $8.62 per thousand board feet. This same procedure was repeated for all appraisal zones, although in some zones the difference in sale sizes was subtracted rather than added because overbid declined as sales grew larger. The adjusted overbids are shown in the following tabulation. A minus sign indicates that overbids on set-aside sales are less than on open sales.

	Zone		
Region	1	2	3
1	--	-3.11	--
5	5.05	-5.66	1.95
6	2.98	-8.62	--

The Government's net implicit payment to small firms can be estimated by aggregating these differences weighted by sale volumes. The total net implicit payment for the 2-year period and for all zones was $13.036 million ($15.610-$2.574) to purchasers of set-aside sales.

The actual implicit payment varies widely on a finer geographic scale. For example, the implicit payment on the three National Forests in southwest Oregon (Umpqua, Rogue River, and Siskiyou) was $15.73 per thousand board feet (Haynes 1979). In this area, the total implicit payment for the 2-year period was slightly more than $10.5 million and was shared by 35 firms. The implicit payment was not shared equally, as seven firms accounted for 52 percent of the set-aside sales.

In Region 5 zones 1 and 3 and in Region 6 zone 1, purchasers of set-aside sales paid more than if the sales had been sold as open sales. This illustrates the intense bidding that many people feel characterizes set-aside sales. This type of bidding may result from frustrations, as suggested by Mead (1966), from differences in sale characteristics between set-aside and open sales, or from potential purchasers' differing perceptions of markets and production alternatives. It is also possible that small firms compete more vigorously on set-aside sales than on open sales in deference to the large firms with whom they have contractual arrangements for selling chips.

The differences in overbid between set-aside sales and open sales raises the larger issue of possible differences between the prices paid for National Forest timber by large and small firms. In general, small firms pay less for National Forest timber in all areas except Region 5 zone 1 and Region 6 zone 1. This is consistent with the observed differences in sale characteristics, particularly size. Sales purchased by small firms are smaller in every zone and, for all six zones, average 2.23 million board feet smaller.

Sale Monitoring

During the 1975-76 period there was little indication of widespread collusive activity. Examination of noncompetitive bidding patterns revealed only a few cases that might warrant investigation. Most noncompetitive sales are so classified because potential bidders probably perceive them as undesirable.

The same techniques used for sale monitoring could also be used to identify sales that have a low probability of being sold as competitive. If these sales were identified before they were offered, in some cases, the sale characteristics might be altered, so as to increase the probability of the sale being sold competitively and, hence, increasing the returns to the U.S. Treasury.

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APPENDIX 1. ANALYTICAL RESULTS FOR EACH APPRAISAL ZONE

Summary results are presented in this appendix for the various analyses carried out during this study. The results are summarized for each appraisal zone. Briefly, these results are:

Tables 8-13	Results for the noncompetitive-competitive sale analysis
Tables 14-19	Results for the sale size analysis
Tables 20-25	Results for the oral-sealed bid analysis
Tables 26-42	Results for the oral-sealed bid (by sale size) analysis
Tables 43-44	Results for the outsider analysis
Tables 45-50	Results for the set-aside-open analysis
Tables 51-56	Results for the set-aside and small open and large open analysis

For all analyses except the sale size analysis and the analysis of set-aside and small open and large open sales, the summary results consisted of sample means ($\bar{x}$) and deviations (s) for each group (i), as well as the pooled deviation (sp) and the $\underline{t}$ statistic for comparing the sample means.

The estimate of pooled variance was computed as:

$$s_p^2 = \sum_{i=1}^{k} s_i^2 (n_i-1)/\sum_{i=1}^{k} n_i-k; \qquad (4)$$

where k is the number of groups and n_i is the sample size of group i. The pooled standard error was computed as:

$$s_p = \sqrt{s_p^2 \frac{(n_1+n_2)}{n_1 n_2}} \; . \qquad (5)$$

The $\underline{t}$ test with n_1+n_2-2 degrees of freedom was:

$$\underline{t} = (x_1 - x_2)/s_p . \qquad (6)$$

When the number of groups was more than two, the summary results consisted of sample means, within mean squares (pooled variance), between mean squares, and an F statistic. A one-way analysis of variance was used to test the hypothesis that the sample means were equal. The between mean squares were computed as follows:

$$\text{Between mean squares} = (\sum_{j=1}^{k} (\bar{x}_j n_j)^2/n_j - (\sum_{j=1}^{k} \bar{x}_j n_j)^2/\sum_{j=1}^{k} n_j)/k-1. \qquad (7)$$

The F statistic is then computed as the ratio of between mean squares and within mean squares with k-1 and $\sum_{j=1}^{k} n_j - k$ degrees of freedom.

TABLE 8--RESULTS FOR NONCOMPETITIVE AND COMPETITIVE ANALYSIS, REGION 1 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS		SAMPLE DEVIATIONS		POOLED DEVIATIONS	T-TEST
	NONCOMP	COMP	NONCOMP	COMP		
VOLUME/ACRE (MBF)	6.59	7.17	4.49	6.50	.77	-.76
SALVAGE STATUS	1.83	1.71	.37	.46	.06	2.28
SET-ASIDE STATUS	1.80	1.89	.40	.32	.04	-2.01
SALES VOLUME (MMBF)	5.98	4.62	5.64	5.38	.70	1.96
MAJOR SPECIES (PERCENT)	18.53	14.42	19.35	16.93	2.25	1.83
APPRAISED STUMPAGE ($/MBF)	5.37	13.85	7.92	13.27	1.54	-5.50
OVERBID ($/MBF)	0.00	11.06	0.00	9.56	1.04	-10.59
ROAD COSTS ($/MBF)	11.22	6.99	9.97	7.67	1.07	3.98
HAUL DISTANCE (MILES)	29.70	33.79	14.97	24.82	2.89	-1.42
LOGGING COST ($/MBF)	47.24	43.33	11.05	8.81	1.21	3.23
MANUFACTURING COSTS ($/MBF)	47.62	49.48	5.82	6.97	.85	-2.18
NUMBER OF BIDDERS	1.77	3.33	1.11	1.95	.23	-6.89
FIBER (PERCENT)	5.35	5.72	15.65	18.19	2.24	-.16
SELLING VALUE ($/MBF)	106.56	120.95	20.10	21.57	2.70	-5.32
TERMINATION PERIOD (YEARS)	3.55	2.85	1.87	1.87	.24	2.94

NOTES

1. NUMBER OF OBSERVATIONS ARE 84 AND 228, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 310 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9667.

TABLE 9--RESULTS FOR NONCOMPETITIVE AND COMPETITIVE ANALYSIS, REGION 5 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS		SAMPLE DEVIATIONS		POOLED DEVIATIONS	T-TEST
	NONCOMP	COMP	NONCOMP	COMP		
VOLUME/ACRE (MBF)	10.71	7.85	12.46	6.57	1.46	1.96
SALVAGE STATUS	1.94	1.86	.24	.35	.06	1.31
SET-ASIDE STATUS	2.00	1.89	0.00	.31	.05	2.01
SALES VOLUME (MMBF)	7.57	9.11	10.17	8.55	1.65	-.93
MAJOR SPECIES (PERCENT)	11.06	8.05	23.24	14.17	2.98	1.01
APPRAISED STUMPAGE ($/MBF)	18.41	15.31	19.28	14.65	2.90	1.07
OVERBID ($/MBF)	0.00	19.62	0.00	18.96	3.26	-6.02
ROAD COSTS ($/MBF)	9.38	7.95	10.31	8.19	1.60	.90
HAUL DISTANCE (MILES)	31.97	31.59	13.72	16.86	3.07	.12
LOGGING COST ($/MBF)	32.06	32.50	11.65	8.92	1.76	-.26
MANUFACTURING COSTS ($/MBF)	38.07	37.93	6.28	6.58	1.22	.12
NUMBER OF BIDDERS	1.97	4.57	1.14	2.42	.42	-6.13
FIBER (PERCENT)	0.00	.58	0.00	4.73	.81	-.72
SELLING VALUE ($/MBF)	103.84	102.71	18.04	18.99	3.53	.32
TERMINATION PERIOD (YEARS)	3.18	3.78	2.46	2.15	.41	-1.45

NOTES

1. NUMBER OF OBSERVATIONS ARE 34 AND 178, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 210 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9704.

TABLE 10--RESULTS FOR NONCOMPETITIVE AND COMPETITIVE ANALYSIS, REGION 5 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS NONCOMP	SAMPLE MEANS COMP	SAMPLE DEVIATIONS NONCOMP	SAMPLE DEVIATIONS COMP	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	5.19	4.58	3.87	5.01	1.64	.37
SALVAGE STATUS	1.80	1.73	.42	.45	.15	.49
SET-ASIDE STATUS	1.90	1.77	.32	.42	.14	.92
SALES VOLUME (MMBF)	5.45	7.18	9.43	7.64	2.61	-.66
MAJOR SPECIES (PERCENT)	14.00	10.54	27.41	20.57	7.11	.49
APPRAISED STUMPAGE ($/MBF)	30.01	16.00	27.71	14.40	5.38	2.60
OVERBID ($/MBF)	0.00	26.71	0.00	19.24	6.11	-4.37
ROAD COSTS ($/MBF)	1.87	5.25	2.59	6.05	1.94	-1.74
HAUL DISTANCE (MILES)	44.10	45.65	20.83	53.01	16.98	-.09
LOGGING COST ($/MBF)	36.27	38.37	16.73	11.97	4.17	-.50
MANUFACTURING COSTS ($/MBF)	37.84	40.43	5.89	6.08	2.02	-1.28
NUMBER OF BIDDERS	1.90	5.24	1.60	2.57	.83	-4.01
FIBER (PERCENT)	0.00	1.21	0.00	10.66	3.39	-.36
SELLING VALUE ($/MBF)	114.50	110.69	21.87	17.85	6.09	.62
TERMINATION PERIOD (YEARS)	2.10	2.97	2.42	2.09	.71	-1.22

NOTES

1. NUMBER OF OBSERVATIONS ARE 10 AND 88, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 96 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9839.

TABLE 11--RESULTS FOR NONCOMPETITIVE AND COMPETITIVE ANALYSIS, REGION 5 ZONE 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS NONCOMP	SAMPLE MEANS COMP	SAMPLE DEVIATIONS NONCOMP	SAMPLE DEVIATIONS COMP	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	13.90	8.41	17.38	11.22	2.97	1.85
SALVAGE STATUS	1.84	1.63	.37	.48	.12	1.80
SET-ASIDE STATUS	1.95	1.89	.23	.32	.08	.79
SALES VOLUME (MMBF)	3.92	5.97	7.84	6.80	1.70	-1.21
MAJOR SPECIES (PERCENT)	26.31	24.61	28.01	24.47	6.11	.28
APPRAISED STUMPAGE ($/MBF)	23.58	14.16	20.12	13.11	3.46	2.72
OVERBID ($/MBF)	0.00	29.75	0.00	22.74	5.23	-5.69
ROAD COSTS ($/MBF)	5.83	6.82	10.37	7.66	1.97	-.50
HAUL DISTANCE (MILES)	36.89	35.92	27.70	30.73	7.45	.13
LOGGING COST ($/MBF)	35.31	37.15	12.49	15.91	3.81	-.48
MANUFACTURING COSTS ($/MBF)	34.38	40.60	10.02	14.91	3.53	-1.76
NUMBER OF BIDDERS	2.16	5.69	1.80	2.70	.64	-5.51
FIBER (PERCENT)	0.00	1.71	0.00	10.98	2.53	-.67
SELLING VALUE ($/MBF)	107.78	108.82	25.83	34.94	8.33	-.12
TERMINATION PERIOD (YEARS)	1.89	2.84	2.05	2.11	.52	-1.82

NOTES

1. NUMBER OF OBSERVATIONS ARE 19 AND 134, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 151 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9748.

TABLE 12--RESULTS FOR NONCOMPETITIVE AND COMPETITIVE ANALYSIS, REGION 6 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS		SAMPLE DEVIATIONS		POOLED	
	NONCOMP	COMP	NONCOMP	COMP	DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	5.77	7.36	5.93	7.90	.68	-2.35
SALVAGE STATUS	1.76	1.79	.43	.41	.04	-.79
SET-ASIDE STATUS	1.89	1.77	.32	.42	.04	3.15
SALES VOLUME (MMBF)	5.91	6.10	6.37	5.29	.55	-.33
MAJOR SPECIES (PERCENT)	47.74	46.57	36.77	37.86	3.56	.33
APPRAISED STUMPAGE ($/MBF)	15.96	17.31	16.04	15.87	1.52	-.89
OVERBID ($/MBF)	.01	17.12	.02	16.30	1.16	-14.69
ROAD COSTS ($/MBF)	5.25	5.31	6.27	5.84	.57	-.10
HAUL DISTANCE (MILES)	33.77	35.03	14.35	17.21	1.52	-.83
LOGGING COST ($/MBF)	35.24	32.70	9.61	8.16	.84	3.03
MANUFACTURING COSTS ($/MBF)	49.26	50.51	9.11	9.58	.89	-1.40
NUMBER OF BIDDERS	1.84	4.10	1.07	2.08	.16	-13.89
FIBER (PERCENT)	4.13	4.41	14.01	10.16	1.14	-.24
SELLING VALUE ($/MBF)	115.76	117.58	21.03	19.94	1.94	-.94
TERMINATION PERIOD (YEARS)	3.29	3.53	1.82	1.75	.17	-1.43

NOTES

1. NUMBER OF OBSERVATIONS ARE 196 AND 253, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 447 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9643.

TABLE 13--RESULTS FOR NONCOMPETITIVE AND COMPETITIVE ANALYSIS, REGION 6 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS		SAMPLE DEVIATIONS		POOLED	
	NONCOMP	COMP	NONCOMP	COMP	DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	16.64	23.02	17.88	20.59	2.37	-2.69
SALVAGE STATUS	1.53	1.67	.50	.48	.06	-2.41
SET-ASIDE STATUS	1.89	1.78	.32	.42	.05	2.22
SALES VOLUME (MMBF)	2.00	4.76	4.00	5.29	.61	-4.56
MAJOR SPECIES (PERCENT)	57.18	54.40	40.07	28.24	3.37	.82
APPRAISED STUMPAGE ($/MBF)	32.40	31.44	25.28	19.70	2.33	.41
OVERBID ($/MBF)	0.00	38.67	0.00	30.54	3.44	-11.25
ROAD COSTS ($/MBF)	3.42	6.12	8.37	8.02	.93	-2.89
HAUL DISTANCE (MILES)	35.77	39.41	18.95	17.14	2.00	-1.82
LOGGING COST ($/MBF)	45.30	39.10	18.51	11.78	1.43	4.35
MANUFACTURING COSTS ($/MBF)	50.58	55.71	12.78	10.27	1.21	-4.24
NUMBER OF BIDDERS	1.66	6.86	1.83	3.10	.35	-14.74
FIBER (PERCENT)	12.39	13.11	22.14	13.35	1.63	-.45
SELLING VALUE ($/MBF)	145.17	148.59	31.00	25.00	2.95	-1.16
TERMINATION PERIOD (YEARS)	1.56	3.01	1.62	1.74	.20	-7.26

NOTES

1. NUMBER OF OBSERVATIONS ARE 79 AND 1240, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 1317 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9608.

TABLE 14--RESULTS FOR SALE SIZE
ANALYSIS, REGION 1 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS 0-.5MMBF	.5-1MMBF	1-2MMBF	2-5MMBF	5-8MMBF	8-15MMBF	15MMBF+	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	5.15	3.78	8.20	7.39	8.40	8.44	9.02	149.61	34.05	4.39
SALVAGE STATUS	1.57	1.35	1.78	1.84	1.83	1.89	2.00	1.70	.16	10.45
SET-ASIDE STATUS	1.94	1.90	1.94	1.71	1.79	1.93	1.86	.43	.11	3.78
SALES VOLUME (MMBF)	.42	.78	1.62	3.52	6.49	11.52	18.92	1443.31	2.17	665.66
MAJOR SPECIES (PERCENT)	14.52	16.78	14.44	19.50	16.70	12.53	10.55	357.54	311.63	1.15
APPRAISED STUMPAGE ($/MBF)	19.60	19.55	8.97	10.07	5.70	5.37	7.40	1788.12	127.49	14.03
OVERBID ($/MBF)	7.72	10.17	8.63	6.53	8.80	8.72	7.12	61.60	91.50	.67
ROAD COSTS ($/MBF)	.93	3.62	4.38	11.92	12.67	13.55	11.75	1383.82	47.25	29.29
HAUL DISTANCE (MILES)	27.56	31.77	30.03	33.29	33.25	42.00	32.71	1014.69	502.80	2.02
LOGGING COST ($/MBF)	40.52	44.50	45.17	45.46	46.79	45.90	44.28	258.30	89.01	2.90
MANUFACTURING COSTS ($/MBF)	48.49	49.15	49.31	48.26	50.44	49.27	48.08	29.53	45.51	.65
NUMBER OF BIDDERS	2.32	2.55	2.88	3.08	3.27	3.33	3.29	8.05	3.51	2.30
FIBER (PERCENT)	6.25	3.20	10.40	4.11	3.39	9.24	1.57	376.14	305.70	1.23
SELLING VALUE ($/MBF)	121.62	127.76	110.45	118.02	113.17	110.79	115.34	1510.55	468.19	3.23
COMPETITIVE STATUS	1.78	1.87	1.84	1.67	1.65	1.69	1.67	.32	.19	1.67
TERMINATION PERIOD (YEARS)	1.03	1.52	1.88	3.35	4.33	4.89	6.05	139.51	.90	154.41

NOTES

1. NUMBER OF OBSERVATIONS ARE 72, 31, 32, 63, 48, 45, AND 21, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 6 AND 305 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.1527.

TABLE 15--RESULTS FOR SALE SIZE
ANALYSIS, REGION 5 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS 0-.5MMBF	.5-1MMBF	1-2MMBF	2-5MMBF	5-8MMBF	8-15MMBF	15MMBF+	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	7.05	7.79	6.94	6.83	9.03	8.34	10.50	61.48	61.55	1.00
SALVAGE STATUS	1.58	1.60	1.83	1.89	2.00	2.00	2.00	1.06	.08	12.61
SET-ASIDE STATUS	1.97	1.93	2.00	1.86	1.86	1.85	1.95	.11	.08	1.37
SALES VOLUME (MMBF)	.28	.83	1.52	3.24	6.43	10.92	23.24	2459.04	8.07	304.53
MAJOR SPECIES (PERCENT)	11.29	4.33	1.68	10.45	11.21	9.82	5.35	318.06	252.37	1.26
APPRAISED STUMPAGE ($/MBF)	28.79	22.88	16.23	9.71	13.94	10.73	13.05	1667.35	197.67	8.43
OVERBID ($/MBF)	12.30	6.90	13.73	12.10	20.81	20.52	19.84	739.88	342.25	2.16
ROAD COSTS ($/MBF)	0.00	2.77	1.81	9.19	8.54	13.09	11.98	905.87	48.80	18.56
HAUL DISTANCE (MILES)	30.11	28.27	35.25	35.57	30.14	31.13	32.02	152.82	271.32	.56
LOGGING COST ($/MBF)	30.21	34.50	31.18	34.78	34.80	34.30	29.07	204.72	84.60	2.42
MANUFACTURING COSTS ($/MBF)	33.77	36.46	38.19	39.45	39.43	39.67	38.24	161.60	39.01	4.14
NUMBER OF BIDDERS	2.08	2.27	3.17	4.11	4.67	5.26	5.30	59.60	4.47	13.34
FIBER (PERCENT)	0.00	3.33	0.00	.76	0.00	0.00	.74	26.01	18.56	1.40
SELLING VALUE ($/MBF)	103.73	107.87	97.05	101.98	104.33	103.51	101.13	170.39	358.81	.47
COMPETITIVE STATUS	1.71	1.73	1.92	1.93	1.95	1.83	1.86	.23	.13	1.75
TERMINATION PERIOD (YEARS)	.55	1.33	1.92	3.32	4.05	5.04	5.05	140.61	.89	157.91

NOTES

1. NUMBER OF OBSERVATIONS ARE 38, 15, 12, 28, 21, 54, AND 44, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 6 AND 205 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.1764.

TABLE 16--RESULTS FOR SALE SIZE
ANALYSIS, REGION 5 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS 0-.5MMBF	.5-1MMBF	1-2MMBF	2-5MMBF	5-8MMBF	8-15MMBF	15MMBF+	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	1.46	1.46	2.17	5.47	7.79	5.09	8.64	120.60	17.51	6.89
SALVAGE STATUS	1.38	1.14	1.58	2.00	2.00	2.00	1.89	1.39	.11	12.33
SET-ASIDE STATUS	1.95	1.86	1.92	1.71	2.00	1.40	1.79	.57	.15	3.94
SALES VOLUME (MMBF)	.27	.94	1.59	3.88	6.16	10.82	20.21	861.88	7.27	118.61
MAJOR SPECIES (PERCENT)	9.21	.03	12.66	8.43	8.81	12.44	17.36	313.64	456.77	.69
APPRAISED STUMPAGE ($/MBF)	23.26	20.92	17.86	13.18	5.68	16.11	18.61	342.85	267.48	1.28
OVERBID ($/MBF)	17.28	27.53	18.82	22.99	28.30	24.32	32.39	458.61	395.36	1.16
ROAD COSTS ($/MBF)	0.00	.30	2.35	7.39	5.72	11.40	5.98	240.98	20.81	11.58
HAUL DISTANCE (MILES)	38.81	52.00	33.08	48.18	49.43	72.07	33.47	2759.90	2597.55	1.06
LOGGING COST ($/MBF)	33.89	40.42	41.60	42.67	48.02	35.02	34.66	322.02	144.20	2.23
MANUFACTURING COSTS ($/MBF)	37.61	42.09	39.70	41.63	40.26	39.41	41.81	41.52	36.74	1.13
NUMBER OF BIDDERS	3.62	4.14	3.75	5.12	4.29	5.53	6.84	22.02	6.08	3.62
FIBER (PERCENT)	0.00	0.00	8.84	0.00	0.00	0.00	0.00	136.81	102.03	1.34
SELLING VALUE ($/MBF)	105.57	116.14	111.21	115.27	109.78	112.62	110.72	183.89	339.74	.54
COMPETITIVE STATUS	1.81	1.86	1.83	1.94	2.00	2.00	1.89	.08	.09	.86
TERMINATION PERIOD (YEARS)	.43	.86	1.42	2.88	3.43	4.93	5.42	59.39	.78	76.55

NOTES

1. NUMBER OF OBSERVATIONS ARE 19, 7, 12, 17, 7, 15, AND 19, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 6 AND 89 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.2705.

TABLE 17--RESULTS FOR SALE SIZE
ANALYSIS, REGION 5 ZONE 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS 0-.5MMBF	.5-1MMBF	1-2MMBF	2-5MMBF	5-8MMBF	8-15MMBF	15MMBF+	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	11.15	13.08	6.55	7.63	6.31	7.71	7.24	129.04	150.08	.86
SALVAGE STATUS	1.29	1.36	1.38	1.94	2.00	2.00	2.00	2.94	.11	25.68
SET-ASIDE STATUS	1.96	1.93	2.00	1.94	1.71	1.83	1.89	.18	.09	2.03
SALES VOLUME (MMBF)	.25	.72	1.62	3.65	6.36	10.99	23.77	1128.69	3.81	296.04
MAJOR SPECIES (PERCENT)	19.88	22.80	20.71	23.83	27.25	32.12	29.56	584.80	618.53	.95
APPRAISED STUMPAGE ($/MBF)	23.77	18.48	13.62	11.97	6.98	9.57	9.05	1144.13	169.71	6.74
OVERBID ($/MBF)	24.29	26.66	24.77	32.30	18.67	29.23	27.69	344.65	557.84	.62
ROAD COSTS ($/MBF)	.23	1.30	2.80	10.78	12.17	13.58	11.67	878.80	30.78	28.55
HAUL DISTANCE (MILES)	32.71	34.57	27.12	52.44	29.94	38.14	38.71	1070.82	910.88	1.18
LOGGING COST ($/MBF)	35.27	34.19	34.04	39.51	42.50	35.54	39.93	193.15	242.24	.80
MANUFACTURING COSTS ($/MBF)	37.30	36.72	41.83	40.94	39.56	42.38	44.01	168.08	212.37	.79
NUMBER OF BIDDERS	4.23	5.36	5.25	6.19	5.29	5.90	6.24	16.15	7.81	2.07
FIBER (PERCENT)	4.39	0.00	0.00	0.00	0.00	0.00	0.00	110.47	105.64	1.05
SELLING VALUE ($/MBF)	107.12	100.41	102.86	112.11	109.93	110.83	114.95	335.58	1178.37	.34
COMPETITIVE STATUS	1.77	2.00	2.00	1.88	1.82	1.97	1.94	.21	.11	2.03
TERMINATION PERIOD (YEARS)	.54	1.29	1.63	3.13	4.29	4.90	5.41	98.53	.64	153.46

NOTES

1. NUMBER OF OBSERVATIONS ARE 52, 14, 8, 16, 17, 29, AND 17, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 6 AND 146 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.2056.

TABLE 18--RESULTS FOR SALE SIZE
ANALYSIS, REGION 6 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS 0-.5MMBF	.5-1MMBF	1-2MMBF	2-5MMBF	5-8MMBF	8-15MMBF	15MMBF+	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	4.52	2.33	4.44	7.42	7.78	9.14	7.31	346.85	47.00	7.38
SALVAGE STATUS	1.36	1.29	1.54	1.87	1.98	2.00	2.00	5.53	.10	53.46
SET-ASIDE STATUS	1.92	1.87	1.83	1.80	1.82	1.74	1.89	.25	.14	1.70
SALES VOLUME (MMBF)	.29	.74	1.61	3.37	6.46	11.04	19.23	2293.11	2.76	832.29
MAJOR SPECIES (PERCENT)	46.25	59.68	45.56	35.50	43.14	48.93	68.29	6568.31	1325.03	4.96
APPRAISED STUMPAGE ($/MBF)	17.42	21.90	13.57	17.15	18.01	14.27	16.53	404.37	252.05	1.60
OVERBID ($/MBF)	4.50	7.60	8.69	8.60	13.22	13.48	7.36	702.84	215.21	3.27
ROAD COSTS ($/MBF)	.05	.54	2.83	4.87	8.86	8.08	9.08	819.52	25.63	31.98
HAUL DISTANCE (MILES)	32.32	36.33	32.56	33.69	33.46	35.58	38.76	254.32	256.67	.99
LOGGING COST ($/MBF)	36.15	33.41	32.86	33.60	33.56	34.16	32.32	74.37	79.34	.94
MANUFACTURING COSTS ($/MBF)	48.16	50.27	50.18	49.22	49.32	51.28	51.58	88.81	88.15	1.01
NUMBER OF BIDDERS	2.32	2.33	3.00	3.27	3.54	3.54	3.03	15.65	4.04	3.87
FIBER (PERCENT)	6.40	3.27	9.25	4.64	2.41	2.22	3.93	354.95	140.66	2.52
SELLING VALUE ($/MBF)	114.99	119.59	110.53	115.34	113.64	117.39	121.29	658.54	413.83	1.59
COMPETITIVE STATUS	1.49	1.51	1.58	1.55	1.60	1.65	1.45	.31	.25	1.24
TERMINATION PERIOD (YEARS)	1.00	1.60	1.98	3.20	4.46	5.08	5.39	175.58	.84	208.37

NOTES

1. NUMBER OF OBSERVATIONS ARE 53, 45, 48, 102, 65, 98, AND 38, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 6 AND 442 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.1377.

TABLE 19--RESULTS FOR SALE SIZE
ANALYSIS, REGION 6 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS 0-.5MMBF	.5-1MMBF	1-2MMBF	2-5MMBF	5-8MMBF	8-15MMBF	15MMBF+	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	14.84	14.24	16.31	24.37	28.59	32.77	36.79	13126.48	361.54	36.31
SALVAGE STATUS	1.32	1.45	1.45	1.77	1.97	1.96	1.97	15.90	.15	104.08
SET-ASIDE STATUS	1.90	1.89	1.75	1.75	1.67	1.73	1.75	1.60	.16	9.98
SALES VOLUME (MMBF)	.23	.73	1.45	3.45	6.46	10.72	19.23	5629.70	2.08	2711.83
MAJOR SPECIES (PERCENT)	55.10	54.27	56.06	52.64	54.82	57.29	48.73	883.92	841.76	1.05
APPRAISED STUMPAGE ($/MBF)	36.33	34.76	30.85	30.05	27.99	29.20	26.95	2352.09	393.06	5.98
OVERBID ($/MBF)	22.54	30.20	32.79	40.51	46.05	46.11	49.34	19918.44	873.46	22.80
ROAD COSTS ($/MBF)	.89	1.88	3.22	7.51	10.35	11.13	10.43	3788.05	47.98	78.94
HAUL DISTANCE (MILES)	38.29	38.84	40.06	39.23	39.51	39.31	41.68	140.36	297.12	.47
LOGGING COST ($/MBF)	43.46	42.18	39.61	39.28	37.50	35.78	34.33	1912.11	142.73	13.40
MANUFACTURING COSTS ($/MBF)	53.96	56.34	55.99	55.17	56.22	56.45	55.48	195.91	105.42	1.87
NUMBER OF BIDDERS	3.60	5.71	6.48	7.35	7.92	8.44	9.46	770.90	7.25	106.40
FIBER (PERCENT)	12.13	13.98	16.36	12.70	12.32	11.69	15.60	514.78	195.20	2.64
SELLING VALUE ($/MBF)	151.41	151.88	145.67	147.81	143.21	148.14	141.31	1563.09	607.94	2.57
COMPETITIVE STATUS	1.82	1.97	1.98	1.98	1.98	1.96	1.99	.97	.05	18.54
TERMINATION PERIOD (YEARS)	1.11	1.64	2.03	3.06	4.35	4.86	5.59	508.66	.78	648.26

NOTES

1. NUMBER OF OBSERVATIONS ARE 305, 150, 157, 237, 183, 214, AND 71, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 6 AND 1310 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.1155.

TABLE 20--RESULTS FOR ORAL AND SEALED BID ANALYSIS, REGION 1 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	8.14	5.81	7.10	6.93	1.00	2.33
SALVAGE STATUS	1.71	1.57	.46	.50	.07	2.03
SET-ASIDE STATUS	1.97	1.90	.17	.30	.04	1.70
SALES VOLUME (MMBF)	6.18	2.61	7.02	4.10	.71	5.00
MAJOR SPECIES (PERCENT)	12.55	17.59	14.36	20.24	2.71	-1.85
APPRAISED STUMPAGE ($/MBF)	19.06	23.04	15.75	16.27	2.31	-1.72
OVERBID ($/MBF)	7.25	9.26	9.63	8.98	1.31	-1.54
ROAD COSTS ($/MBF)	9.91	4.72	11.81	8.67	1.37	3.80
HAUL DISTANCE (MILES)	34.14	31.87	18.15	18.39	2.62	.86
LOGGING COST ($/MBF)	49.24	47.76	9.52	11.57	1.59	.93
MANUFACTURING COSTS ($/MBF)	53.80	53.96	10.93	9.15	1.38	-.11
NUMBER OF BIDDERS	2.23	2.51	1.07	1.57	.21	-1.31
FIBER (PERCENT)	10.36	8.59	26.18	25.12	3.63	.49
SELLING VALUE ($/MBF)	146.39	144.66	24.45	22.27	3.27	.53
COMPETITIVE STATUS	1.74	1.88	.44	.32	.05	-2.83
TERMINATION PERIOD (YEARS)	3.28	1.90	1.90	1.68	.25	5.52

NOTES

1. NUMBER OF OBSERVATIONS ARE 65 AND 196, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 259 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9682.

TABLE 21--RESULTS FOR ORAL AND SEALED BID ANALYSIS, REGION 5 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	6.15	6.13	4.82	8.40	1.18	.02
SALVAGE STATUS	1.67	1.41	.47	.49	.08	3.37
SET-ASIDE STATUS	1.91	1.91	.28	.29	.05	.09
SALES VOLUME (MMBF)	10.27	2.14	9.61	4.43	1.01	8.02
MAJOR SPECIES (PERCENT)	7.20	4.82	12.28	12.24	1.93	1.23
APPRAISED STUMPAGE ($/MBF)	24.65	24.58	14.61	14.19	2.25	.03
OVERBID ($/MBF)	33.63	18.23	28.61	17.32	3.36	4.58
ROAD COSTS ($/MBF)	9.10	2.36	7.43	6.21	1.04	6.49
HAUL DISTANCE (MILES)	35.03	34.30	14.10	13.70	2.17	.34
LOGGING COST ($/MBF)	41.04	40.36	10.23	12.20	1.83	.37
MANUFACTURING COSTS ($/MBF)	42.98	31.08	6.38	18.73	2.52	4.72
NUMBER OF BIDDERS	3.95	2.88	1.88	2.00	.31	3.45
FIBER (PERCENT)	0.00	3.56	0.00	12.65	1.66	-2.14
SELLING VALUE ($/MBF)	131.05	109.85	16.67	31.90	4.44	4.78
COMPETITIVE STATUS	1.90	1.80	.31	.40	.06	1.68
TERMINATION PERIOD (YEARS)	3.91	1.24	2.50	1.59	.30	8.89

NOTES

1. NUMBER OF OBSERVATIONS ARE 58 AND 133, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 189 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9717.

TABLE 22--RESULTS FOR ORAL AND SEALED BID
ANALYSIS, REGION 5 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	3.44	6.59	2.53	8.77	1.79	-1.76
SALVAGE STATUS	1.19	1.71	.40	.48	.12	-4.43
SET-ASIDE STATUS	1.77	1.71	.43	.46	.12	.45
SALES VOLUME (MMBF)	8.05	6.13	5.86	6.39	1.67	1.15
MAJOR SPECIES (PERCENT)	3.63	8.13	6.28	15.73	3.31	-1.36
APPRAISED STUMPAGE ($/MBF)	25.51	27.34	14.63	17.31	4.38	-.42
OVERBID ($/MBF)	19.33	31.12	18.65	25.19	6.07	-1.94
ROAD COSTS ($/MBF)	5.99	5.87	4.80	7.49	1.73	.07
HAUL DISTANCE (MILES)	53.35	40.32	25.89	15.41	5.75	2.27
LOGGING COST ($/MBF)	42.63	36.59	8.72	7.50	2.21	2.73
MANUFACTURING COSTS ($/MBF)	42.11	44.12	6.33	12.09	2.66	-.76
NUMBER OF BIDDERS	4.69	4.46	2.88	3.01	.80	.28
SELLING VALUE ($/MBF)	130.37	126.27	18.11	23.76	5.78	.71
COMPETITIVE STATUS	1.81	1.89	.40	.31	.10	-.87
TERMINATION PERIOD (YEARS)	2.12	2.00	1.53	2.07	.50	.23

NOTES

1. NUMBER OF OBSERVATIONS ARE 26 AND 28, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 52 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.0051.

TABLE 23--RESULTS FOR ORAL AND SEALED BID
ANALYSIS, REGION 5 ZONE 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	8.41	9.30	5.29	12.25	3.35	-.26
SALVAGE STATUS	1.93	1.41	.27	.50	.14	3.76
SET-ASIDE STATUS	1.79	1.60	.43	.49	.14	1.31
SALES VOLUME (MMBF)	12.81	2.18	9.29	4.07	1.54	6.90
MAJOR SPECIES (PERCENT)	29.27	27.10	23.90	31.12	8.81	.25
APPRAISED STUMPAGE ($/MBF)	20.55	28.11	10.99	15.18	4.27	-1.77
OVERBID ($/MBF)	50.39	25.16	13.39	21.86	6.07	4.15
ROAD COSTS ($/MBF)	13.57	3.92	6.14	7.20	2.36	4.68
HAUL DISTANCE (MILES)	37.00	30.91	23.47	19.57	5.93	1.03
LOGGING COST ($/MBF)	45.09	39.72	9.45	12.19	3.45	1.55
MANUFACTURING COSTS ($/MBF)	45.97	40.44	11.96	9.52	2.91	1.90
NUMBER OF BIDDERS	6.57	3.80	1.74	2.55	.71	3.89
SELLING VALUE ($/MBF)	138.95	124.68	20.24	20.06	5.88	2.43
COMPETITIVE STATUS	2.00	1.89	0.00	.32	.09	1.33
TERMINATION PERIOD (YEARS)	4.86	1.21	1.61	1.60	.47	7.78

NOTES

1. NUMBER OF OBSERVATIONS ARE 14 AND 70, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 82 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9882.

TABLE 24--RESULTS FOR ORAL AND SEALED BID
ANALYSIS, REGION 6 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	6.05	6.71	5.63	8.37	.90	-.73
SALVAGE STATUS	1.66	1.57	.47	.50	.06	1.60
SET-ASIDE STATUS	1.80	1.82	.40	.39	.05	-.38
SALES VOLUME (MMBF)	6.04	4.41	5.97	5.29	.72	2.27
MAJOR SPECIES (PERCENT)	54.72	45.89	37.30	42.06	5.03	1.76
APPRAISED STUMPAGE ($/MBF)	36.82	31.09	17.10	17.14	2.18	2.63
OVERBID ($/MBF)	10.81	11.63	15.90	13.88	1.91	-.43
ROAD COSTS ($/MBF)	4.85	2.93	6.17	4.77	.71	2.71
HAUL DISTANCE (MILES)	33.45	33.87	14.75	13.96	1.83	-.23
LOGGING COST ($/MBF)	38.07	38.09	10.48	9.61	1.28	-.01
MANUFACTURING COSTS ($/MBF)	54.12	48.32	6.14	12.32	1.21	4.80
NUMBER OF BIDDERS	2.73	2.76	1.74	1.71	.22	-.11
FIBER (PERCENT)	1.35	1.86	8.95	11.32	1.28	-.40
SELLING VALUE ($/MBF)	150.87	135.45	17.13	26.97	2.82	5.46
COMPETITIVE STATUS	1.66	1.86	.47	.35	.05	-3.68
TERMINATION PERIOD (YEARS)	3.22	2.39	1.73	1.83	.23	3.65

NOTES

1. NUMBER OF OBSERVATIONS ARE 134 AND 115, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 247 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9687.

TABLE 25--RESULTS FOR ORAL AND SEALED BID
ANALYSIS, REGION 6 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	22.68	21.77	17.71	21.29	1.62	.56
SALVAGE STATUS	1.70	1.60	.46	.49	.04	2.55
SET-ASIDE STATUS	1.87	1.69	.33	.46	.03	5.42
SALES VOLUME (MMBF)	5.02	4.10	5.15	4.90	.40	2.27
MAJOR SPECIES (PERCENT)	59.28	54.63	27.25	31.34	2.42	1.92
APPRAISED STUMPAGE ($/MBF)	52.82	48.98	18.12	17.41	1.43	2.68
OVERBID ($/MBF)	28.52	36.16	24.81	31.14	2.35	-3.26
ROAD COSTS ($/MBF)	5.36	4.29	7.07	6.48	.54	2.02
HAUL DISTANCE (MILES)	38.32	37.87	16.50	16.39	1.33	.34
LOGGING COST ($/MBF)	45.70	44.10	15.91	11.51	1.08	1.48
MANUFACTURING COSTS ($/MBF)	65.86	59.76	10.57	11.53	.91	6.73
NUMBER OF BIDDERS	5.47	5.46	3.08	3.22	.26	.05
FIBER (PERCENT)	9.10	8.63	9.77	8.34	.72	.64
SELLING VALUE ($/MBF)	192.19	177.21	30.62	25.85	2.24	6.67
COMPETITIVE STATUS	1.94	1.96	.23	.19	.02	-1.29
TERMINATION PERIOD (YEARS)	3.16	2.21	1.77	1.64	.14	6.93

NOTES

1. NUMBER OF OBSERVATIONS ARE 242 AND 412, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 652 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9626.

TABLE 26--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE)
ANALYSIS, REGION I ZONE 2 GROUP I

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	7.33	4.76	8.82	6.68	1.51	1.70
SALVAGE STATUS	1.42	1.41	.50	.49	.11	.15
SET-ASIDE STATUS	1.96	1.95	.20	.22	.05	.29
SALES VOLUME (MMBF)	.95	.43	1.02	.45	.12	4.20
MAJOR SPECIES (PERCENT)	9.74	16.27	14.40	20.97	4.30	-1.52
APPRAISED STUMPAGE ($/MBF)	21.68	26.45	19.31	16.12	3.57	-1.34
OVERBID ($/MBF)	6.38	7.49	11.14	7.94	1.83	-.61
ROAD COSTS ($/MBF)	5.51	1.17	11.33	4.21	1.27	3.42
HAUL DISTANCE (MILES)	36.92	29.98	21.48	17.49	3.89	1.78
LOGGING COST ($/MBF)	47.95	47.85	7.04	11.66	2.37	.04
MANUFACTURING COSTS ($/MBF)	49.95	54.02	15.84	9.28	2.27	-1.79
NUMBER OF BIDDERS	2.04	2.32	1.11	1.55	.32	-.88
FIBER (PERCENT)	20.36	9.74	38.93	27.23	6.29	1.69
SELLING VALUE ($/MBF)	140.66	145.48	36.18	22.74	5.42	-1.00
COMPETITIVE STATUS	1.65	1.87	.49	.34	.08	-2.70
TERMINATION PERIOD (YEARS)	1.85	.99	1.38	.64	.17	4.97

NOTES

1. NUMBER OF OBSERVATIONS ARE 26 AND 135, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 159 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9740.
4. GROUP 1 ARE SALES BETWEEN 0 AND 2000 MBF.

TABLE 27--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE)
ANALYSIS, REGION I ZONE 2 GROUP 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	7.92	5.91	3.94	4.39	1.11	1.81
SALVAGE STATUS	1.83	1.90	.39	.31	.09	-.80
SET-ASIDE STATUS	1.96	1.95	.21	.37	.08	1.32
SALES VOLUME (MMBF)	4.62	4.84	1.69	1.78	.46	-.48
MAJOR SPECIES (PERCENT)	16.74	23.28	13.49	19.36	4.58	-1.43
APPRAISED STUMPAGE ($/MBF)	17.29	14.05	12.07	13.47	3.41	.95
OVERBID ($/MBF)	6.52	12.28	7.25	9.62	2.32	-2.48
ROAD COSTS ($/MBF)	10.24	12.50	9.55	11.04	2.77	-.82
HAUL DISTANCE (MILES)	28.35	33.95	13.33	15.48	3.87	-1.45
LOGGING COST ($/MBF)	51.94	49.15	12.77	11.86	3.21	.87
MANUFACTURING COSTS ($/MBF)	56.56	53.35	4.17	10.48	2.29	1.40
NUMBER OF BIDDERS	2.13	2.79	.81	1.45	.33	-2.01
FIBER (PERCENT)	3.16	5.24	7.21	18.50	4.04	-.52
SELLING VALUE ($/MBF)	150.19	142.15	10.53	23.19	5.13	1.57
COMPETITIVE STATUS	1.74	1.90	.45	.31	.10	-1.65
TERMINATION PERIOD (YEARS)	3.26	3.44	1.21	1.37	.35	-.51

NOTES

1. NUMBER OF OBSERVATIONS ARE 23 AND 39, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 60 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9989.
4. GROUP 2 ARE SALES BETWEEN 2000 AND 8000 MBF.

TABLE 28--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 1 ZONE 2 GROUP 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	9.78	12.11	7.66	8.81	2.74	-.85
SALVAGE STATUS	2.00	1.95	0.00	.21	.05	.85
SET-ASIDE STATUS	2.00	1.73	0.00	.46	.11	2.38
SALES VOLUME (MMBF)	16.93	12.07	5.46	3.91	1.52	3.20
MAJOR SPECIES (PERCENT)	11.11	15.55	14.96	15.62	5.04	-.88
APPRAISED STUMPAGE ($/MBF)	17.33	17.99	14.26	14.82	4.79	-.14
OVERBID ($/MBF)	9.71	14.74	10.15	10.46	3.40	-1.48
ROAD COSTS ($/MBF)	16.59	12.76	12.90	10.13	3.73	1.03
HAUL DISTANCE (MILES)	37.94	39.82	17.18	25.68	7.40	-.25
LOGGING COST ($/MBF)	47.46	44.74	6.87	10.37	2.98	.91
MANUFACTURING COSTS ($/MBF)	56.10	54.63	4.78	5.24	1.66	.88
NUMBER OF BIDDERS	2.69	3.14	1.25	1.73	.51	-.88
FIBER (PERCENT)	4.48	7.42	5.75	21.92	5.64	-.52
SELLING VALUE ($/MBF)	151.20	144.10	9.52	17.78	4.90	1.45
COMPETITIVE STATUS	1.88	1.95	.34	.21	.09	-.88
TERMINATION PERIOD (YEARS)	5.63	4.77	.81	1.38	.39	2.21

NOTES

1. NUMBER OF OBSERVATIONS ARE 16 AND 22, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 36 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.0256.
4. GROUP 3 ARE SALES OVER 8000 MBF.

TABLE 29--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 5 ZONE 1 GROUP 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	3.66	5.81	5.16	9.10	2.27	-.94
SALVAGE STATUS	1.12	1.29	.33	.45	.11	-1.46
SET-ASIDE STATUS	2.00	1.96	0.00	.19	.05	.81
SALES VOLUME (MMBF)	.77	.39	.58	.44	.12	3.13
MAJOR SPECIES (PERCENT)	5.32	4.43	15.00	12.42	3.34	.27
APPRAISED STUMPAGE ($/MBF)	28.58	26.46	13.93	13.97	3.65	.58
OVERBID ($/MBF)	12.01	14.46	12.46	14.01	3.61	-.68
ROAD COSTS ($/MBF)	1.41	.28	2.96	1.66	.49	2.28
HAUL DISTANCE (MILES)	33.24	34.80	16.78	13.82	3.73	-.42
LOGGING COST ($/MBF)	44.60	39.83	9.98	11.53	2.96	1.61
MANUFACTURING COSTS ($/MBF)	40.54	28.23	10.91	20.12	5.01	2.46
NUMBER OF BIDDERS	2.53	2.37	1.46	1.60	.41	.38
FIBER (PERCENT)	0.00	4.51	0.00	14.10	3.43	-1.31
SELLING VALUE ($/MBF)	129.52	106.15	21.60	34.22	8.58	2.72
COMPETITIVE STATUS	1.76	1.76	.44	.43	.11	.03
TERMINATION PERIOD (YEARS)	.82	.58	.61	.63	.17	1.41

NOTES

1. NUMBER OF OBSERVATIONS ARE 17 AND 105, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 120 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9789.
4. GROUP 1 ARE SALES BETWEEN 0 AND 2000 MBF.

TABLE 30--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 5 ZONE 1 GROUP 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	5.03	6.62	3.13	4.64	1.74	-.91
SALVAGE STATUS	1.78	1.81	.44	.40	.17	-.20
SET-ASIDE STATUS	1.89	1.88	.33	.34	.14	.10
SALES VOLUME (MMBF)	4.72	4.32	1.44	1.72	.68	.58
MAJOR SPECIES (PERCENT)	8.61	9.65	10.45	14.45	5.50	-.19
APPRAISED STUMPAGE ($/MBF)	17.68	18.30	10.03	14.10	5.34	-.12
OVERBID ($/MBF)	43.15	26.77	39.49	21.03	12.01	1.36
ROAD COSTS ($/MBF)	14.61	10.02	6.85	11.56	4.24	1.08
HAUL DISTANCE (MILES)	40.11	29.56	15.10	12.35	5.57	1.89
LOGGING COST ($/MBF)	41.58	45.57	6.62	16.72	5.86	-.68
MANUFACTURING COSTS ($/MBF)	44.22	41.59	4.66	2.17	1.36	1.94
NUMBER OF BIDDERS	4.00	4.38	1.73	2.06	.81	-.46
SELLING VALUE ($/MBF)	131.25	128.04	16.61	12.70	5.91	.54
COMPETITIVE STATUS	1.89	1.88	.33	.34	.14	.10
TERMINATION PERIOD (YEARS)	3.33	2.81	1.22	1.56	.60	.86

NOTES

1. NUMBER OF OBSERVATIONS ARE 9 AND 16, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 23 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.0632.
4. GROUP 2 ARE SALES BETWEEN 2000 AND 8000 MBF.

TABLE 31--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 5 ZONE 1 GROUP 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	8.65	6.06	5.06	2.69	1.54	1.68
SALVAGE STATUS	1.94	2.00	.25	0.00	.07	-.87
SET-ASIDE STATUS	1.69	2.00	.47	0.00	.14	-2.28
SALES VOLUME (MMBF)	13.55	23.46	6.08	5.64	2.02	-4.91
MAJOR SPECIES (PERCENT)	5.62	7.66	8.86	13.45	3.47	-.59
APPRAISED STUMPAGE ($/MBF)	21.80	23.77	16.57	9.94	5.12	-.38
OVERBID ($/MBF)	39.86	46.74	23.41	25.98	3.16	-.84
ROAD COSTS ($/MBF)	10.87	12.39	6.30	7.02	2.20	-.69
HAUL DISTANCE (MILES)	35.69	33.25	13.52	10.50	4.33	.56
LOGGING COST ($/MBF)	39.01	38.06	12.09	4.82	3.61	.26
MANUFACTURING COSTS ($/MBF)	43.15	44.01	2.34	1.93	.76	-1.13
NUMBER OF BIDDERS	4.88	4.83	2.04	1.64	.66	.06
SELLING VALUE ($/MBF)	126.89	131.13	16.72	11.84	5.28	-.80
COMPETITIVE STATUS	1.97	2.00	.18	0.00	.05	-.61
TERMINATION PERIOD (YEARS)	5.09	6.58	1.23	1.08	.40	-3.69

NOTES

1. NUMBER OF OBSERVATIONS ARE 32 AND 12, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 42 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.0161.
4. GROUP 3 ARE SALES OVER 8000 MBF.

TABLE 32--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 5 ZONE 2 GROUP 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	1.27	5.55	1.84	11.35	4.73	-.90
SALVAGE STATUS	1.17	1.43	.41	.51	.24	-1.10
SET-ASIDE STATUS	1.83	2.00	.41	0.00	.10	-1.59
SALES VOLUME (MMBF)	1.14	.94	.45	.92	.40	.52
MAJOR SPECIES (PERCENT)	1.88	8.16	2.85	13.77	5.76	-1.09
APPRAISED STUMPAGE ($/MBF)	38.26	31.75	16.83	20.94	9.70	.67
OVERBID ($/MBF)	12.92	8.23	13.88	7.08	4.62	1.01
ROAD COSTS ($/MBF)	.72	.91	1.13	1.89	.83	-.23
HAUL DISTANCE (MILES)	44.00	36.64	11.93	12.98	6.20	1.19
LOGGING COST ($/MBF)	40.67	34.82	5.80	4.59	2.42	2.42
MANUFACTURING COSTS ($/MBF)	44.10	38.33	1.52	7.48	3.13	1.84
NUMBER OF BIDDERS	2.67	2.07	1.37	1.00	.54	1.10
SELLING VALUE ($/MBF)	139.18	116.65	13.07	26.33	11.42	1.97
COMPETITIVE STATUS	1.67	1.79	.52	.43	.22	-.54
TERMINATION PERIOD (YEARS)	1.00	.36	0.00	.84	.35	1.84

NOTES

1. NUMBER OF OBSERVATIONS ARE 6 AND 14, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 18 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.0922.
4. GROUP 1 ARE SALES BETWEEN 0 AND 2000 MBF.

TABLE 33--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 5 ZONE 2 GROUP 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	3.25	8.81	1.65	4.62	1.76	-3.15
SALVAGE STATUS	1.25	2.00	.46	0.00	.24	-3.16
SET-ASIDE STATUS	1.75	1.25	.46	.50	.29	1.72
SALES VOLUME (MMBF)	5.50	6.07	1.87	1.72	1.12	-.51
MAJOR SPECIES (PERCENT)	6.50	2.90	9.57	2.61	4.98	.72
APPRAISED STUMPAGE ($/MBF)	20.48	15.37	14.01	6.33	7.48	.68
OVERBID ($/MBF)	18.79	48.37	17.00	10.20	9.36	-3.16
ROAD COSTS ($/MBF)	6.90	16.01	5.50	9.45	4.24	-2.15
HAUL DISTANCE (MILES)	52.12	45.25	24.19	23.84	14.75	.47
LOGGING COST ($/MBF)	44.90	42.67	10.82	10.77	6.62	.34
MANUFACTURING COSTS ($/MBF)	39.79	51.26	10.12	16.33	7.54	-1.52
NUMBER OF BIDDERS	5.38	5.75	2.77	1.71	1.53	-.24
SELLING VALUE ($/MBF)	124.59	139.21	28.17	19.66	15.87	-.92
COMPETITIVE STATUS	1.88	2.00	.35	0.00	.18	-.69
TERMINATION PERIOD (YEARS)	2.50	2.50	1.69	1.00	.93	0.00

NOTES

1. NUMBER OF OBSERVATIONS ARE 8 AND 4, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 10 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.1987.
4. GROUP 2 ARE SALES BETWEEN 2000 AND 8000 MBF.

TABLE 34--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 5 ZONE 2 GROUP 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	4.65	7.16	2.66	5.77	1.86	-1.35
SALVAGE STATUS	1.17	2.00	.39	0.00	.12	-6.74
SET-ASIDE STATUS	1.75	1.50	.45	.53	.21	1.20
SALES VOLUME (MMBF)	13.21	13.41	3.97	4.39	1.78	-.11
MAJOR SPECIES (PERCENT)	2.58	10.19	4.33	21.19	6.24	-1.22
APPRAISED STUMPAGE ($/MBF)	22.49	25.94	10.75	12.49	4.95	-.70
OVERBID ($/MBF)	22.89	56.28	21.96	12.05	7.78	-4.29
ROAD COSTS ($/MBF)	8.03	8.77	3.50	6.32	2.13	-.35
HAUL DISTANCE (MILES)	58.83	43.50	31.70	15.37	10.99	1.40
LOGGING COST ($/MBF)	42.08	36.65	8.76	8.86	3.77	1.44
MANUFACTURING COSTS ($/MBF)	42.66	49.37	4.29	12.79	3.92	-1.71
NUMBER OF BIDDERS	5.25	7.30	3.19	2.50	1.24	-1.65
SELLING VALUE ($/MBF)	129.83	134.56	9.78	16.40	5.64	-.84
COMPETITIVE STATUS	1.83	2.00	.39	0.00	.12	-1.35
TERMINATION PERIOD (YEARS)	2.42	4.10	1.62	1.52	.68	-2.49

NOTES

1. NUMBER OF OBSERVATIONS ARE 12 AND 10, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 20 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.0788.
4. GROUP 3 ARE SALES OVER 8000 MBF.

TABLE 35--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 5 ZONE 3 GROUP 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	6.83	12.33	3.86	12.48	4.92	-1.12
SALVAGE STATUS	1.86	2.00	.38	0.00	.12	-1.15
SET-ASIDE STATUS	2.00	1.44	0.00	.53	.20	2.77
SALES VOLUME (MMBF)	6.12	3.72	1.03	1.59	.69	3.46
MAJOR SPECIES (PERCENT)	35.61	41.56	26.51	31.27	14.78	-.40
APPRAISED STUMPAGE ($/MBF)	18.53	17.31	12.43	6.95	4.88	.25
OVERBID ($/MBF)	52.71	35.86	13.77	15.50	7.45	2.26
ROAD COSTS ($/MBF)	13.43	13.43	6.79	9.99	4.41	.00
HAUL DISTANCE (MILES)	28.86	33.67	16.57	19.19	9.13	-.53
LOGGING COST ($/MBF)	44.83	44.20	6.88	5.93	3.20	.20
MANUFACTURING COSTS ($/MBF)	41.77	46.32	2.25	8.41	3.29	-1.38
NUMBER OF BIDDERS	5.86	5.44	1.07	1.42	.65	.64
SELLING VALUE ($/MBF)	131.35	134.58	10.65	17.21	7.44	-.43
TERMINATION PERIOD (YEARS)	4.00	3.11	1.41	1.27	.67	1.32

NOTES

1. NUMBER OF OBSERVATIONS ARE 7 AND 9, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 14 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.1302.
4. GROUP 2 ARE SALES BETWEEN 2000 AND 8000 MBF.

TABLE 36--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 5 ZONE 3 GROUP 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	10.00	8.04	6.31	5.20	3.24	.60
SET-ASIDE STATUS	1.57	1.67	.53	.52	.29	-.33
SALES VOLUME (MMBF)	19.50	13.96	9.03	5.00	4.16	1.33
MAJOR SPECIES (PERCENT)	22.93	34.77	26.99	18.89	11.16	-1.06
APPRAISED STUMPAGE ($/MBF)	22.57	16.84	9.83	11.93	6.05	.95
OVERBID ($/MBF)	48.08	51.55	13.66	11.42	7.06	-.49
ROAD COSTS ($/MBF)	13.71	14.97	5.97	6.24	3.39	-.37
HAUL DISTANCE (MILES)	45.14	36.83	27.64	19.11	13.43	.62
LOGGING COST ($/MBF)	45.34	38.62	12.09	6.44	5.52	1.22
MANUFACTURING COSTS ($/MBF)	50.18	44.71	16.27	5.62	7.01	.78
NUMBER OF BIDDERS	7.29	8.33	2.06	2.50	1.26	-.83
SELLING VALUE ($/MBF)	146.56	127.56	25.29	18.44	12.48	1.52
TERMINATION PERIOD (YEARS)	5.71	4.83	1.38	.98	.68	1.30

NOTES

1. NUMBER OF OBSERVATIONS ARE 7 AND 6, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 11 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 2.1769.
4. GROUP 3 ARE SALES OVER 8000 MBF.

TABLE 37--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 6 ZONE 1 GROUP 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	3.61	4.63	5.49	6.15	1.14	-.90
SALVAGE STATUS	1.29	1.28	.46	.45	.09	.11
SET-ASIDE STATUS	1.73	1.91	.45	.28	.07	-2.52
SALES VOLUME (MMBF)	.98	.49	.64	.45	.11	4.66
MAJOR SPECIES (PERCENT)	61.68	43.04	41.87	43.01	8.25	2.26
APPRAISED STUMPAGE ($/MBF)	35.44	29.08	18.56	17.74	3.52	1.81
OVERBID ($/MBF)	8.00	5.97	15.16	6.04	2.17	.94
ROAD COSTS ($/MBF)	1.70	.47	5.81	2.27	.83	1.49
HAUL DISTANCE (MILES)	33.31	33.21	14.47	12.75	2.63	.04
LOGGING COST ($/MBF)	38.67	39.25	11.24	9.68	2.02	-.29
MANUFACTURING COSTS ($/MBF)	53.78	47.33	5.24	14.12	2.13	3.02
NUMBER OF BIDDERS	2.27	2.33	1.51	1.39	.28	-.22
FIBER (PERCENT)	1.15	.26	3.94	1.39	.55	1.61
SELLING VALUE ($/MBF)	146.23	130.86	14.02	28.06	4.41	3.48
COMPETITIVE STATUS	1.57	1.79	.50	.41	.09	-2.52
TERMINATION PERIOD (YEARS)	1.65	.91	.93	.66	.15	4.82

NOTES

1. NUMBER OF OBSERVATIONS ARE 49 AND 58, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 105 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9818.
4. GROUP 1 ARE SALES BETWEEN 0 AND 2000 MBF.

TABLE 38--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 6 ZONE I GROUP 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	7.12	6.58	6.42	5.33	1.42	.37
SALVAGE STATUS	1.82	1.79	.39	.42	.09	.41
SET-ASIDE STATUS	1.80	1.71	.40	.46	.10	.90
SALES VOLUME (MMBF)	5.13	4.77	1.60	1.81	.39	.93
MAJOR SPECIES (PERCENT)	41.85	51.60	36.20	39.66	8.81	-1.11
APPRAISED STUMPAGE ($/MBF)	33.80	31.76	14.82	14.73	3.48	.59
OVERBID ($/MBF)	7.14	15.81	10.19	17.36	3.09	-2.80
ROAD COSTS ($/MBF)	6.19	4.69	5.93	6.01	1.40	1.06
HAUL DISTANCE (MILES)	32.00	34.04	14.14	15.31	3.42	-.59
LOGGING COST ($/MBF)	39.85	38.61	10.22	7.51	2.20	.56
MANUFACTURING COSTS ($/MBF)	55.42	50.36	5.39	7.08	1.42	3.56
NUMBER OF BIDDERS	.24	0.30	1.72	1.96	.43	.57
FIBER (PERCENT)	2.63	3.00	.81	0.00	.15	-2.42
SELLING VALUE ($/MBF)	152.62	140.90	14.49	17.42	3.66	3.20
COMPETITIVE STATUS	1.63	1.36	.49	.19	.10	-3.50
TERMINATION PERIOD (YEARS)	3.55	3.04	1.46	1.23	.33	1.58

NOTES

1. NUMBER OF OBSERVATIONS ARE 51 AND 28, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 77 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9901.
4. GROUP 2 ARE SALES BETWEEN 2000 AND 8000 MBF.

TABLE 39--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 6 ZONE I GROUP 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	7.97	10.99	4.06	12.37	2.25	-1.34
SALVAGE STATUS	1.97	1.93	.17	.26	.05	.73
SET-ASIDE STATUS	1.88	1.72	.33	.45	.10	1.60
SALES VOLUME (MMBF)	14.70	11.91	4.75	4.47	1.17	2.39
MAJOR SPECIES (PERCENT)	63.99	46.09	25.62	43.22	6.80	2.03
APPRAISED STUMPAGE ($/MBF)	43.33	34.47	16.84	18.07	4.40	2.01
OVERBID ($/MBF)	20.36	18.94	20.00	16.75	4.70	.31
ROAD COSTS ($/MBF)	7.38	6.16	5.18	4.59	1.24	.99
HAUL DISTANCE (MILES)	35.82	35.03	16.14	15.28	3.98	.20
LOGGING COST ($/MBF)	34.55	35.25	9.07	10.92	2.52	-.28
MANUFACTURING COSTS ($/MBF)	52.67	48.33	7.94	12.56	2.61	1.66
NUMBER OF BIDDERS	3.56	3.38	1.85	1.84	.47	.39
FIBER (PERCENT)	3.31	6.87	17.12	21.97	4.93	-.72
SELLING VALUE ($/MBF)	154.95	139.37	22.92	31.24	6.84	2.28
COMPETITIVE STATUS	1.85	1.90	.36	.31	.09	-.51
TERMINATION PERIOD (YEARS)	4.97	4.72	.76	.88	.21	1.19

NOTES

1. NUMBER OF OBSERVATIONS ARE 34 AND 29, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 61 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9983.
4. GROUP 3 ARE SALES OVER 8000 MBF.

TABLE 40--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 6 ZONE 2 GROUP 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	14.63	13.70	14.85	21.09	2.33	.15
SALVAGE STATUS	1.39	1.32	.49	.47	.06	1.30
SET-ASIDE STATUS	1.89	1.78	.31	.41	.05	2.35
SALES VOLUME (MMBF)	.69	.56	.51	.54	.06	2.07
MAJOR SPECIES (PERCENT)	62.15	52.60	28.80	34.89	3.99	2.39
APPRAISED STUMPAGE ($/MBF)	53.95	48.51	17.53	18.53	2.20	2.47
OVERBID ($/MBF)	19.42	32.12	18.55	37.26	3.91	-3.25
ROAD COSTS ($/MBF)	.66	1.16	2.44	3.82	.41	-1.20
HAUL DISTANCE (MILES)	37.06	36.62	16.48	15.04	1.88	.23
LOGGING COST ($/MBF)	49.49	47.43	21.20	13.24	1.97	1.04
MANUFACTURING COSTS ($/MBF)	67.01	58.00	14.50	14.38	1.74	5.17
NUMBER OF BIDDERS	3.75	3.88	2.36	2.57	.30	-.41
FIBER (PERCENT)	8.17	6.93	12.60	8.31	1.20	1.04
SELLING VALUE ($/MBF)	193.45	174.81	38.65	30.17	4.01	4.65
COMPETITIVE STATUS	1.88	1.93	.32	.25	.03	-1.50
TERMINATION PERIOD (YEARS)	1.60	1.00	.76	.81	.10	6.19

NOTES

1. NUMBER OF OBSERVATIONS ARE 102 AND 208, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 308 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9668.
4. GROUP 1 ARE SALES BETWEEN 0 AND 2000 MBF.

TABLE 41--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 6 ZONE 2 GROUP 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	26.10	26.13	15.60	15.29	2.23	-.01
SALVAGE STATUS	1.90	1.83	.31	.38	.05	1.26
SET-ASIDE STATUS	1.88	1.55	.32	.50	.06	5.19
SALES VOLUME (MMBF)	4.86	4.68	1.63	1.64	.24	.75
MAJOR SPECIES (PERCENT)	57.14	56.70	28.79	28.64	4.16	.11
APPRAISED STUMPAGE ($/MBF)	53.64	50.20	21.07	17.69	2.76	1.25
OVERBID ($/MBF)	36.07	38.34	30.06	23.59	3.80	-.60
ROAD COSTS ($/MBF)	8.88	7.06	8.42	7.41	1.13	1.60
HAUL DISTANCE (MILES)	37.23	38.51	16.13	16.34	2.36	-.54
LOGGING COST ($/MBF)	42.89	41.23	9.85	8.38	1.30	1.28
MANUFACTURING COSTS ($/MBF)	65.38	61.90	6.74	5.74	.89	3.91
NUMBER OF BIDDERS	6.32	6.62	2.69	2.91	.41	-.71
FIBER (PERCENT)	9.20	9.94	6.63	7.55	1.05	-.70
SELLING VALUE ($/MBF)	193.58	180.69	26.03	21.35	3.37	3.83
COMPETITIVE STATUS	2.00	1.99	0.00	.09	.01	.78
TERMINATION PERIOD (YEARS)	3.69	2.77	1.22	1.14	.17	5.42

NOTES

1. NUMBER OF OBSERVATIONS ARE 77 AND 125, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 200 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9710.
4. GROUP 2 ARE SALES BETWEEN 2000 AND 8000 MBF.

TABLE 42--RESULTS FOR ORAL AND SEALED BID (BY SALE SIZE) ANALYSIS, REGION 6 ZONE 2 GROUP 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS ORAL	SAMPLE MEANS SEALED	SAMPLE DEVIATIONS ORAL	SAMPLE DEVIATIONS SEALED	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	32.51	36.11	18.03	20.59	3.29	-1.10
SALVAGE STATUS	1.95	1.97	.21	.16	.03	-.71
SET-ASIDE STATUS	1.83	1.65	.38	.48	.07	2.42
SALES VOLUME (MMBF)	12.21	12.49	4.00	4.04	.68	-.41
MAJOR SPECIES (PERCENT)	57.23	56.73	22.27	24.87	4.01	.12
APPRAISED STUMPAGE ($/MBF)	49.97	48.36	14.87	13.61	2.40	.70
OVERBID ($/MBF)	34.01	43.34	22.08	20.89	3.62	-2.58
ROAD COSTS ($/MBF)	8.75	8.12	5.86	6.47	1.05	.60
HAUL DISTANCE (MILES)	41.68	40.13	16.78	19.50	3.10	.50
LOGGING COST ($/MBF)	42.99	39.87	9.61	7.81	1.46	2.14
MANUFACTURING COSTS ($/MBF)	64.58	61.01	5.64	9.06	1.31	2.73
NUMBER OF BIDDERS	7.21	7.78	3.16	3.05	.52	-1.11
FIBER (PERCENT)	10.47	11.06	7.45	8.74	1.38	-.43
SELLING VALUE ($/MBF)	188.44	178.01	19.02	18.60	3.17	3.29
COMPETITIVE STATUS	1.97	2.00	.18	0.00	.02	-1.60
TERMINATION PERIOD (YEARS)	5.03	4.49	1.20	.88	.17	3.08

NOTES

1. NUMBER OF OBSERVATIONS ARE 63 AND 79, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 140 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9761.
4. GROUP 3 ARE SALES OVER 8000 MBF.

TABLE 43--RESULTS FOR INSIDER AND OUTSIDER ANALYSIS, REGION 6 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS INSIDERS	SAMPLE MEANS OUTSIDERS	SAMPLE DEVIATIONS INSIDERS	SAMPLE DEVIATIONS OUTSIDERS	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	6.16	6.03	6.45	8.90	.64	-2.93
SALVAGE STATUS	1.72	1.77	.45	.42	.04	-1.17
SET-ASIDE STATUS	1.85	1.72	.36	.45	.03	3.77
SALES VOLUME (MMBF)	5.56	6.54	5.62	5.86	.50	-1.94
MAJOR SPECIES (PERCENT)	48.12	45.74	37.94	38.74	3.39	.70
APPRAISED STUMPAGE ($/MBF)	21.73	23.42	17.80	19.54	1.62	-1.04
OVERBID ($/MBF)	7.89	15.28	13.08	16.57	1.25	-5.92
ROAD COSTS ($/MBF)	5.02	4.76	6.22	5.20	.53	.49
HAUL DISTANCE (MILES)	34.12	34.80	15.58	16.07	1.39	-.49
LOGGING COST ($/MBF)	35.43	34.93	9.69	9.34	.85	.59
MANUFACTURING COSTS ($/MBF)	50.27	50.42	9.58	8.80	.83	-.18
NUMBER OF BIDDERS	2.62	4.32	1.74	2.15	.17	-8.49
FIBER (PERCENT)	3.10	3.75	10.51	11.65	.96	-.67
SELLING VALUE ($/MBF)	124.90	126.38	24.17	25.65	2.18	-.68
COMPETITIVE STATUS	1.56	1.81	.50	.39	.04	-6.05
TERMINATION PERIOD (YEARS)	3.21	3.42	1.79	1.84	.16	-1.29

NOTES

1. NUMBER OF OBSERVATIONS ARE 485 AND 172, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 655 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9626.

TABLE 44--RESULTS FOR INSIDER AND OUTSIDER ANALYSIS, REGION 6 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS INSIDERS	SAMPLE MEANS OUTSIDERS	SAMPLE DEVIATIONS INSIDERS	SAMPLE DEVIATIONS OUTSIDERS	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	22.40	23.22	20.57	19.51	1.20	-.68
SALVAGE STATUS	1.63	1.73	.48	.44	.03	-3.53
SET-ASIDE STATUS	1.80	1.72	.40	.45	.02	3.15
SALES VOLUME (MMBF)	4.52	4.89	5.28	4.98	.31	-1.17
MAJOR SPECIES (PERCENT)	53.89	60.48	28.99	29.93	1.72	-3.82
APPRAISED STUMPAGE ($/MBF)	37.38	36.47	21.11	21.38	1.25	.73
OVERBID ($/MBF)	33.81	42.18	29.78	30.26	1.77	-4.74
ROAD COSTS ($/MBF)	5.45	6.19	7.61	8.11	.46	-1.62
HAUL DISTANCE (MILES)	38.92	39.03	17.02	17.21	1.01	-.11
LOGGING COST ($/MBF)	40.71	42.03	11.97	15.61	.75	-1.75
MANUFACTURING COSTS ($/MBF)	57.20	58.05	10.81	11.99	.65	-1.30
NUMBER OF BIDDERS	6.05	7.04	3.30	3.11	.19	-5.14
FIBER (PERCENT)	12.22	10.48	12.90	12.67	.76	2.29
SELLING VALUE ($/MBF)	158.19	160.30	28.87	34.57	1.77	-1.19
COMPETITIVE STATUS	1.94	1.97	.23	.18	.01	-1.75
TERMINATION PERIOD (YEARS)	2.81	2.76	1.77	1.77	.10	.45

NOTES

1. NUMBER OF OBSERVATIONS ARE 1536 AND 352, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 1886 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9602.

TABLE 45--RESULTS FOR SET-ASIDE AND OPEN ANALYSIS, REGION 1 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS SET-ASIDE	SAMPLE MEANS OPEN	SAMPLE DEVIATIONS SET-ASIDE	SAMPLE DEVIATIONS OPEN	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	8.09	6.84	5.86	6.04	.99	1.27
SALVAGE STATUS	1.79	1.73	.41	.44	.07	.81
SALES VOLUME (MMBF)	5.23	4.94	4.65	5.60	.90	.32
MAJOR SPECIES (PERCENT)	14.62	15.67	15.90	17.97	2.91	-.36
APPRAISED STUMPAGE ($/MBF)	7.42	12.23	9.06	13.00	2.06	-2.33
OVERBID ($/MBF)	5.59	8.48	8.13	9.70	1.56	-1.85
ROAD COSTS ($/MBF)	11.09	7.65	8.21	8.52	1.39	2.47
HAUL DISTANCE (MILES)	30.42	33.06	13.49	23.78	3.72	-.71
LOGGING COST ($/MBF)	45.12	44.26	8.98	9.71	1.58	.54
MANUFACTURING COSTS ($/MBF)	47.88	49.15	7.49	6.59	1.10	-1.15
NUMBER OF BIDDERS	3.40	2.83	1.93	1.88	.31	1.81
SELLING VALUE ($/MBF)	108.90	118.38	19.83	22.19	3.59	-2.64
COMPETITIVE STATUS	1.60	1.75	.49	.43	.07	-2.01
TERMINATION PERIOD (YEARS)	3.56	2.95	1.53	1.93	.31	1.96

NOTES

1. NUMBER OF OBSERVATIONS ARE 43 AND 269, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 310 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9667.

TABLE 46--RESULTS FOR SET-ASIDE AND OPEN
ANALYSIS, REGION 5 ZONE 1

SALE CHARACTERISTICS	SAMPLE MEANS		SAMPLE DEVIATIONS		POOLED	
AND UNITS	SET-ASIDE	OPEN	SET-ASIDE	OPEN	DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	9.66	8.17	7.06	7.92	1.89	.78
SALVAGE STATUS	2.00	1.86	0.00	.35	.08	1.75
SALES VOLUME (MMBF)	9.23	8.83	6.80	9.01	2.13	.19
MAJOR SPECIES (PERCENT)	14.27	7.96	15.06	15.95	3.82	1.65
APPRAISED STUMPAGE ($/MBF)	11.74	16.20	10.74	15.83	3.72	-1.20
OVERBID ($/MBF)	21.09	16.02	15.56	19.07	4.52	1.12
ROAD COSTS ($/MBF)	12.44	7.76	7.87	8.52	2.04	2.30
HAUL DISTANCE (MILES)	29.21	31.89	12.43	16.71	3.94	-.68
LOGGING COST ($/MBF)	32.87	32.39	4.43	9.74	2.26	.21
MANUFACTURING COSTS ($/MBF)	41.87	37.56	3.70	6.61	1.54	2.79
NUMBER OF BIDDERS	5.05	4.07	2.41	2.45	.59	1.67
SELLING VALUE ($/MBF)	107.48	102.44	11.78	19.32	4.52	1.12
COMPETITIVE STATUS	2.00	1.82	0.00	.38	.09	2.01
TERMINATION PERIOD (YEARS)	4.95	3.55	1.35	2.24	.52	2.66

NOTES

1. NUMBER OF OBSERVATIONS ARE 19 AND 193, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 210 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9704.

TABLE 47--RESULTS FOR SET-ASIDE AND OPEN
ANALYSIS, REGION 5 ZONE 2

SALE CHARACTERISTICS	SAMPLE MEANS		SAMPLE DEVIATIONS		POOLED	
AND UNITS	SET-ASIDE	OPEN	SET-ASIDE	OPEN	DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	5.89	4.30	4.58	4.95	1.20	1.32
SALVAGE STATUS	1.95	1.68	.22	.47	.11	2.61
SALES VOLUME (MMBF)	9.12	6.43	6.25	8.12	1.91	1.41
MAJOR SPECIES (PERCENT)	10.88	10.89	16.75	22.38	5.25	-.00
APPRAISED STUMPAGE ($/MBF)	24.96	15.38	16.94	16.00	3.99	2.40
OVERBID ($/MBF)	17.73	25.69	16.71	20.51	4.87	-1.64
ROAD COSTS ($/MBF)	7.21	4.28	5.40	5.87	1.42	2.06
HAUL DISTANCE (MILES)	40.38	46.88	20.20	56.15	12.51	-.52
LOGGING COST ($/MBF)	34.46	39.16	8.40	13.20	3.04	-1.55
MANUFACTURING COSTS ($/MBF)	39.78	40.27	5.88	6.17	1.50	-.33
NUMBER OF BIDDERS	4.38	5.04	1.69	2.89	.66	-1.00
SELLING VALUE ($/MBF)	119.56	108.77	14.84	18.43	4.37	2.47
COMPETITIVE STATUS	1.95	1.88	.22	.32	.07	.92
TERMINATION PERIOD (YEARS)	4.24	2.51	1.48	2.13	.50	3.49

NOTES

1. NUMBER OF OBSERVATIONS ARE 21 AND 77, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 96 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9839.

TABLE 48--RESULTS FOR SET-ASIDE AND OPEN
ANALYSIS, REGION 5 ZONE 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS SET-ASIDE	OPEN	SAMPLE DEVIATIONS SET-ASIDE	OPEN	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	9.99	8.99	13.90	12.06	3.24	.31
SALVAGE STATUS	1.81	1.64	.40	.48	.13	1.36
SALES VOLUME (MMBF)	8.43	5.40	6.16	6.98	1.82	1.66
MAJOR SPECIES (PERCENT)	21.87	25.16	18.47	25.52	6.58	-.50
APPRAISED STUMPAGE ($/MBF)	11.09	15.82	9.66	14.83	3.81	-1.24
OVERBID ($/MBF)	27.70	25.87	20.21	23.85	6.21	.29
ROAD COSTS ($/MBF)	9.76	6.34	7.77	8.00	2.11	1.62
HAUL DISTANCE (MILES)	28.13	36.96	19.27	31.24	8.00	-1.11
LOGGING COST ($/MBF)	36.54	36.97	9.72	16.07	4.11	-.10
MANUFACTURING COSTS ($/MBF)	43.17	39.43	7.82	15.07	3.83	.97
NUMBER OF BIDDERS	5.56	5.21	2.22	2.92	.76	.46
SELLING VALUE ($/MBF)	111.01	108.42	17.09	35.35	8.98	.29
COMPETITIVE STATUS	1.94	1.87	.25	.34	.09	.79
TERMINATION PERIOD (YEARS)	4.06	2.56	2.14	2.07	.55	2.73

NOTES

1. NUMBER OF OBSERVATIONS ARE 16 AND 137, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 151 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9748.

TABLE 49--RESULTS FOR SET-ASIDE AND OPEN
ANALYSIS, REGION 6 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS SET-ASIDE	OPEN	SAMPLE DEVIATIONS SET-ASIDE	OPEN	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	8.31	6.31	7.53	7.02	.88	2.26
SALVAGE STATUS	1.90	1.75	.30	.44	.05	2.96
SALES VOLUME (MMBF)	6.41	5.93	4.77	5.98	.72	.66
MAJOR SPECIES (PERCENT)	33.14	50.06	37.25	36.75	4.57	-3.71
APPRAISED STUMPAGE ($/MBF)	17.20	16.62	16.04	15.94	1.98	.30
OVERBID ($/MBF)	12.69	9.01	16.11	14.56	1.84	2.00
ROAD COSTS ($/MBF)	6.55	5.01	6.16	5.97	.74	2.07
HAUL DISTANCE (MILES)	33.94	34.60	18.02	15.58	1.99	-.33
LOGGING COST ($/MBF)	32.11	34.17	7.14	9.20	1.10	-1.88
MANUFACTURING COSTS ($/MBF)	51.73	49.59	8.68	9.50	1.16	1.84
NUMBER OF BIDDERS	4.10	2.90	1.80	2.04	.25	4.84
FIBER (PERCENT)	4.22	4.31	10.13	12.35	1.49	-.06
SELLING VALUE ($/MBF)	118.68	116.38	15.27	21.36	2.53	.91
COMPETITIVE STATUS	1.72	1.53	.45	.50	.06	3.15
TERMINATION PERIOD (YEARS)	4.11	3.28	1.63	1.78	.22	3.82

NOTES

1. NUMBER OF OBSERVATIONS ARE 79 AND 370, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 447 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9643.

TABLE 50--RESULTS FOR SET-ASIDE AND OPEN ANALYSIS, REGION 6 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS SET-ASIDE	OPEN	SAMPLE DEVIATIONS SET-ASIDE	OPEN	POOLED DEVIATIONS	T-TEST
VOLUME/ACRE (MBF)	23.81	22.36	20.06	20.60	1.38	1.04
SALVAGE STATUS	1.78	1.63	.41	.48	.03	4.97
SALES VOLUME (MMBF)	5.82	4.28	5.22	5.23	.35	4.36
MAJOR SPECIES (PERCENT)	56.84	54.07	27.31	29.44	1.96	1.42
APPRAISED STUMPAGE ($/MBF)	32.75	31.22	20.35	19.97	1.35	1.13
OVERBID ($/MBF)	31.85	37.63	23.93	32.52	2.09	-2.77
ROAD COSTS ($/MBF)	7.97	5.42	8.71	7.80	.54	4.72
HAUL DISTANCE (MILES)	42.00	38.51	15.67	17.54	1.16	3.01
LOGGING COST ($/MBF)	38.12	39.91	10.43	12.71	.83	-2.17
MANUFACTURING COSTS ($/MBF)	55.26	55.55	9.55	10.48	.69	-.42
NUMBER OF BIDDERS	6.65	6.54	2.79	3.39	.22	.50
FIBER (PERCENT)	12.31	13.30	10.86	14.75	.95	-1.05
SELLING VALUE ($/MBF)	150.46	148.12	22.45	25.31	1.67	1.40
COMPETITIVE STATUS	1.97	1.93	.18	.25	.02	2.19
TERMINATION PERIOD (YEARS)	3.53	2.77	1.56	1.78	.12	6.46

NOTES

1. NUMBER OF OBSERVATIONS ARE 278 AND 1039, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE T VALUE FOR 1315 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 1.9608.

TABLE 51--RESULTS FOR SET ASIDE, SMALL OPEN AND LARGE OPEN ANALYSIS, REGION 1 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS SET ASIDE	SM OPEN	LR OPEN	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	8.09	6.03	7.33	83.37	35.98	2.32
SALVAGE STATUS	1.79	1.68	1.77	.32	.19	1.66
SALES VOLUME (MMBF)	5.23	2.85	6.22	362.06	27.82	13.01
MAJOR SPECIES (PERCENT)	14.62	14.96	16.10	61.60	314.14	.20
APPRAISED STUMPAGE ($/MBF)	7.42	13.09	11.70	488.81	157.40	3.11
OVERBID ($/MBF)	5.59	7.68	8.97	207.88	90.16	2.31
ROAD COSTS ($/MBF)	11.09	4.27	9.72	1156.60	66.03	17.52
HAUL DISTANCE (MILES)	30.42	28.25	35.99	2030.06	502.86	4.04
LOGGING COST ($/MBF)	45.12	44.04	44.40	17.67	92.76	.19
MANUFACTURING COSTS ($/MBF)	47.88	49.20	49.12	29.90	45.30	.66
NUMBER OF BIDDERS	3.40	2.68	2.93	7.87	3.57	2.21
FIBER (PERCENT)	5.43	4.76	6.19	64.92	308.63	.21
SELLING VALUE ($/MBF)	108.90	116.59	119.47	1926.62	478.99	4.02
COMPETITIVE STATUS	1.60	1.77	1.74	.44	.20	2.26
TERMINATION PERIOD (YEARS)	3.56	2.13	3.46	62.63	3.20	19.60

NOTES

1. NUMBER OF OBSERVATIONS ARE 43, 102, AND 167, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 2 AND 309 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 3.0245.

TABLE 52--RESULTS FOR SET ASIDE, SMALL OPEN AND LARGE OPEN ANALYSIS, REGION 5 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS SET ASIDE	SM OPEN	LR OPEN	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	9.66	7.03	8.77	83.47	61.38	1.36
SALVAGE STATUS	2.00	1.79	1.90	.42	.11	3.87
SALES VOLUME (MMBF)	9.23	6.44	10.07	288.05	75.90	3.80
MAJOR SPECIES (PERCENT)	14.27	7.71	8.10	331.10	253.47	1.31
APPRAISED STUMPAGE ($/MBF)	11.74	16.90	15.84	188.12	240.48	.78
OVERBID ($/MBF)	21.09	17.74	15.13	359.58	353.93	1.02
ROAD COSTS ($/MBF)	12.44	6.88	8.21	219.23	71.74	3.06
HAUL DISTANCE (MILES)	29.21	31.12	32.29	88.89	270.19	.33
LOGGING COST ($/MBF)	32.87	33.11	32.02	27.58	88.93	.31
MANUFACTURING COSTS ($/MBF)	41.87	36.68	38.02	191.42	41.12	4.65
NUMBER OF BIDDERS	5.05	3.89	4.16	9.50	6.00	1.58
FIBER (PERCENT)	0.00	1.25	.17	27.93	18.78	1.49
SELLING VALUE ($/MBF)	107.48	102.86	102.22	218.24	355.68	.61
COMPETITIVE STATUS	2.00	1.83	1.82	.26	.13	1.93
TERMINATION PERIOD (YEARS)	4.95	2.95	3.87	34.02	4.59	7.41

NOTES

1. NUMBER OF OBSERVATIONS ARE 18, 66, AND 127, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 2 AND 208 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 3.0391.

TABLE 53--RESULTS FOR SET ASIDE, SMALL OPEN AND LARGE OPEN ANALYSIS, REGION 5 ZONE 2

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS SET ASIDE	SM OPEN	LR OPEN	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	5.89	4.47	4.21	21.28	24.02	.89
SALVAGE STATUS	1.95	1.52	1.76	1.14	.18	6.47
SALES VOLUME (MMBF)	9.12	3.72	7.90	212.97	57.74	3.69
MAJOR SPECIES (PERCENT)	10.88	5.61	13.74	578.74	447.45	1.29
APPRAISED STUMPAGE ($/MBF)	24.96	17.32	14.33	835.25	263.46	3.17
OVERBID ($/MBF)	17.73	18.52	29.57	1594.56	372.80	4.28
ROAD COSTS ($/MBF)	7.21	2.27	5.36	154.24	31.98	4.82
HAUL DISTANCE (MILES)	40.38	44.67	48.08	450.93	2605.56	.17
LOGGING COST ($/MBF)	34.46	44.44	36.31	761.37	142.06	5.36
MANUFACTURING COSTS ($/MBF)	39.78	38.90	41.01	40.93	36.89	1.11
NUMBER OF BIDDERS	4.38	3.93	5.64	29.33	6.72	4.36
FIBER (PERCENT)	0.00	3.93	0.00	151.03	101.07	1.49
SELLING VALUE ($/MBF)	119.56	112.30	106.86	1220.63	312.63	3.90
COMPETITIVE STATUS	1.95	1.85	1.96	.06	.09	.64
TERMINATION PERIOD (YEARS)	4.24	1.63	2.98	40.72	3.76	10.83

NOTES

1. NUMBER OF OBSERVATIONS ARE 21, 27, AND 50, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 2 AND 95 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 3.0921.

TABLE 54--RESULTS FOR SET ASIDE, SMALL OPEN AND LARGE OPEN ANALYSIS, REGION 5 ZONE 3

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS SET ASIDE	SM OPEN	LR OPEN	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	9.99	5.55	11.29	548.89	143.92	3.81
SALVAGE STATUS	1.81	1.51	1.73	1.02	.22	4.75
SALES VOLUME (MMBF)	6.43	2.58	7.29	429.96	43.13	9.97
MAJOR SPECIES (PERCENT)	21.87	27.59	23.53	349.30	620.77	.56
APPRAISED STUMPAGE ($/MBF)	11.09	16.65	15.27	191.86	208.40	.92
OVERBID ($/MBF)	27.70	19.75	29.97	1745.57	533.48	3.27
ROAD COSTS ($/MBF)	9.76	2.70	8.78	692.52	55.88	12.39
HAUL DISTANCE (MILES)	28.13	41.56	33.88	1531.85	909.00	1.69
LOGGING COST ($/MBF)	36.54	36.33	37.40	20.15	243.24	.08
MANUFACTURING COSTS ($/MBF)	43.17	35.29	42.21	889.69	201.57	4.41
NUMBER OF BIDDERS	5.56	4.65	5.59	15.14	8.04	1.88
FIBER (PERCENT)	0.00	1.87	1.54	21.72	106.95	.20
SELLING VALUE ($/MBF)	111.01	100.84	113.51	2691.75	1126.88	2.39
COMPETITIVE STATUS	1.94	1.84	1.89	.08	.11	.74
TERMINATION PERIOD (YEARS)	4.06	1.82	3.06	41.55	4.01	10.36

NOTES

1. NUMBER OF OBSERVATIONS ARE 16, 55, AND 82, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 2 AND 150 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 3.0563.

TABLE 55--RESULTS FOR SET ASIDE, SMALL OPEN AND LARGE OPEN ANALYSIS, REGION 6 ZONE 1

SALE CHARACTERISTICS AND UNITS	SAMPLE MEANS SET ASIDE	SM OPEN	LR OPEN	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	8.31	6.99	5.95	174.16	50.44	3.45
SALVAGE STATUS	1.90	1.68	1.79	1.25	.17	7.33
SALES VOLUME (MMBF)	6.41	4.07	7.00	380.68	31.87	11.94
MAJOR SPECIES (PERCENT)	33.14	41.75	54.77	16538.02	1326.90	12.46
APPRAISED STUMPAGE ($/MBF)	17.20	15.22	17.48	230.37	253.98	.91
OVERBID ($/MBF)	12.69	8.63	9.19	460.58	220.39	2.09
ROAD COSTS ($/MBF)	6.55	3.43	5.92	346.32	34.86	9.94
HAUL DISTANCE (MILES)	33.94	33.55	35.22	134.94	256.62	.53
LOGGING COST ($/MBF)	32.11	34.82	33.85	183.57	78.99	2.32
MANUFACTURING COSTS ($/MBF)	51.73	49.59	49.58	149.52	87.71	1.70
NUMBER OF BIDDERS	4.10	3.06	2.80	49.99	3.99	12.51
FIBER (PERCENT)	4.22	5.89	3.36	276.87	142.65	1.94
SELLING VALUE ($/MBF)	118.68	114.48	117.59	582.52	416.58	1.40
COMPETITIVE STATUS	1.72	1.53	1.53	1.22	.24	5.03
TERMINATION PERIOD (YEARS)	4.11	2.87	3.51	40.76	3.03	13.44

NOTES

1. NUMBER OF OBSERVATIONS ARE 79, 137, AND 234, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 2 AND 447 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 3.0152.

TABLE 56--RESULTS FOR SET ASIDE, SMALL OPEN AND LARGE OPEN ANALYSIS, REGION 6 ZONE 2

SALE CHARACTERISTICS	SAMPLE MEANS					
AND UNITS	SET ASIDE	SM OPEN	LR OPEN	BETWEEN	WITHIN	F-RATIO
VOLUME/ACRE (MBF)	23.81	21.12	23.62	1036.65	418.80	2.48
SALVAGE STATUS	1.78	1.56	1.69	4.96	.22	22.80
SALES VOLUME (MMBF)	5.82	3.66	4.91	463.46	27.07	17.12
MAJOR SPECIES (PERCENT)	56.84	53.55	54.59	983.64	841.74	1.17
APPRAISED STUMPAGE ($/MBF)	32.75	31.62	30.82	338.53	402.08	.84
OVERBID ($/MBF)	31.85	34.21	41.08	9789.89	946.65	10.34
ROAD COSTS ($/MBF)	7.97	4.57	6.28	1093.50	63.47	17.23
HAUL DISTANCE (MILES)	42.00	38.70	38.33	1352.10	294.80	4.59
LOGGING COST ($/MBF)	38.12	40.56	39.26	573.94	150.15	3.82
MANUFACTURING COSTS ($/MBF)	55.26	53.96	57.16	1336.52	103.96	12.86
NUMBER OF BIDDERS	6.65	6.17	6.91	71.81	10.63	6.75
FIBER (PERCENT)	12.31	13.98	12.62	347.92	196.43	1.77
SELLING VALUE ($/MBF)	150.46	146.71	149.53	1634.09	610.74	2.68
COMPETITIVE STATUS	1.97	1.91	1.95	.36	.06	6.44
TERMINATION PERIOD (YEARS)	3.53	2.54	3.01	91.44	2.97	30.83

NOTES

1. NUMBER OF OBSERVATIONS ARE 278, 522, AND 517, RESPECTIVELY.
2. TO CONVERT STATUS VARIABLES TO PERCENT SUBTRACT THE REPORTED NUMBER FROM 2.0 AND MULTIPLY BY 100.0.
3. THE F VALUE FOR 2 AND 1314 DEGREES OF FREEDOM AND AT THE 5-PERCENT CONFIDENCE LEVEL IS 3.0015.

APPENDIX 2. CORRELATION COEFFICIENTS FOR EACH APPRAISAL ZONE

Tables 57-62

TABLE 57--CORRELATION COEFFICIENTS FOR REGION 1 ZONE 2

SALE CHARACTERISTICS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 VOLUME/ACRE	1.0000														
2 SALVAGE STATUS	-.9974	1.0000													
3 SET-ASIDE STATUS	-.9984	.9956	1.0000												
4 SALE VOLUME	.2396	-.2197	-.2393	1.0000											
5 MAJOR SPECIES	-.1410	.1466	.1413	-.0823	1.0000										
6 APPRAISED STUMPAGE	-.0790	.0679	.0961	-.3443	.0270	1.0000									
7 OVERBID	-.0325	.0325	.0383	-.0025	-.0061	.1296	1.0000								
8 ROAD COSTS	.1143	-.0912	-.1216	.4233	.0859	-.3412	-.1190	1.0000							
9 LOGGING COSTS	-.2113	.2153	.2083	.1217	-.0161	-.3482	-.1574	.1302	1.0000						
10 MANUFACTURING COSTS	-.2283	.2297	.2307	.0098	.0899	.0104	.2933	-.0624	.2490	1.0000					
11 NUMBER OF BIDDERS	-.0317	.0355	.0256	.1569	-.0206	-.0763	.6017	-.0124	-.1497	.2292	1.0000				
12 FIBER	.2474	-.2514	-.2457	.0355	-.2187	-.1599	-.1238	-.0927	-.1656	-.3538	-.0227	1.0000			
13 SELLING VALUE	-.4072	.4023	.4136	-.1951	.0904	.6246	.1369	-.0469	.1330	.4110	-.1674	-.3656	1.0000		
14 COMPETITIVE STATUS	-.0461	.0408	.0438	-.0371	-.0693	-.0266	-.1515	-.1055	-.1764	-.1311	-.0130	.0686	-.0525	1.0000	
15 TERMINATION PERIOD	.0558	-.0546	-.0533	.1201	.1274	.0925	.0714	.0955	.1268	.0981	-.0157	-.1206	.0790	-.8029	1.0000

TABLE 58--CORRELATION COEFFICIENTS FOR REGION 5 ZONE 1

SALE CHARACTERISTICS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 VOLUME/ACRE	1.0000														
2 SALVAGE STATUS	-.9992	1.0000													
3 SET-ASIDE STATUS	-.9993	.9983	1.0000												
4 SALE VOLUME	.1527	-.1396	-.1527	1.0000											
5 MAJOR SPECIES	.0551	-.0528	-.0591	-.0710	1.0000										
6 APPRAISED STUMPAGE	.0996	-.1059	-.0964	-.2320	.1292	1.0000									
7 OVERBID	.0711	-.0694	-.0737	.1651	.0534	-.0567	1.0000								
8 ROAD COSTS	-.1081	.1242	.1021	.4292	.0426	-.3282	-.0425	1.0000							
9 LOGGING COSTS	-.1029	.1039	.1921	-.0938	.1986	-.3311	-.0575	-.0169	1.0000						
10 MANUFACTURING COSTS	.0422	-.0328	-.0490	.1272	.0499	-.1932	.1607	.1862	.2756	1.0000					
11 NUMBER OF BIDDERS	.1359	-.1268	-.1397	.4118	.1373	-.2514	.6704	.1988	.0477	.1870	1.0000				
12 FIBER	-.0586	.0511	.0597	.0269	-.0607	-.0211	.0036	-.0773	-.0038	-.0562	.0492	1.0000			
13 SELLING VALUE	-.3666	.3698	.3638	-.0938	.1962	.5432	-.0425	.1667	.2268	.3542	-.1157	-.0418	1.0000		
14 COMPETITIVE STATUS	-.0610	.0650	.0466	.1057	.0308	.0231	-.2493	.0889	-.1405	-.1556	-.1591	-.0770	.0010	1.0000	
15 TERMINATION PERIOD	.0730	-.0800	-.0624	-.0816	-.0506	.0816	.1219	-.0751	.1250	.0477	.0461	.1039	.0553	-.7989	1.0000

TABLE 59--CORRELATION COEFFICIENTS FOR REGION 5 ZONE 2

SALE CHARACTERISTICS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 VOLUME/ACRE	1.0000														
2 SALVAGE STATUS	-.9964	1.0000													
3 SET-ASIDE STATUS	-.9966	.9914	1.0000												
4 SALE VOLUME	.5120	-.4976	-.5164	1.0000											
5 MAJOR SPECIES	.0775	-.0759	-.0763	.1472	1.0000										
6 APPRAISED STUMPAGE	.0102	-.0140	-.0299	-.0459	-.2013	1.0000									
7 OVERBID	.0316	-.0253	-.0174	.2212	-.1955	-.2342	1.0000								
8 ROAD COSTS	.1219	-.0843	-.1372	.3528	-.0035	-.2226	.1789	1.0000							
9 LOGGING COSTS	.1963	-.1947	-.1835	-.0905	-.0663	-.4950	-.0952	-.1120	1.0000						
10 MANUFACTURING COSTS	.1332	-.1212	-.1285	.2199	-.0936	-.2407	.2394	.1702	.2712	1.0000					
11 NUMBER OF BIDDERS	.0984	-.0814	-.0886	.3931	-.0398	-.2310	.7323	.3445	-.1731	.2022	1.0000				
12 FIBER	-.0617	.0471	.0655	-.0698	-.0556	-.0927	-.1158	-.0904	.2498	.0264	-.1123	1.0000			
13 SELLING VALUE	-.0157	.0298	-.0025	-.0633	-.4181	.5883	-.1598	.0303	.1568	.3225	-.2194	.1039	1.0000		
14 COMPETITIVE STATUS	.3756	-.3775	-.4068	.2742	.0879	.0380	-.1002	-.0191	.0547	-.1023	-.0351	.1564	-.0226	1.0000	
15 TERMINATION PERIOD	-.2924	.2935	.3059	-.1982	.0143	.1520	.0176	-.0499	-.1975	-.0274	-.1256	-.1309	.0349	-.7620	1.0000

TABLE 60--CORRELATION COEFFICIENTS FOR REGION 5 ZONE 3

SALE CHARACTERISTICS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 VOLUME/ACRE	1.0000														
2 SALVAGE STATUS	-.9992	1.0000													
3 SET-ASIDE STATUS	-.9997	.9988	1.0000												
4 SALE VOLUME	-.0934	.1142	.0899	1.0000											
5 MAJOR SPECIES	-.2671	.2796	.2679	.1241	1.0000										
6 APPRAISED STUMPAGE	.3383	-.3467	-.3354	-.3356	-.1274	1.0000									
7 OVERBID	.1428	-.1449	-.1433	.0232	-.1412	-.1084	1.0000								
8 ROAD COSTS	-.1864	.2069	.1829	.5552	.0505	-.4244	.0809	1.0000							
9 LOGGING COSTS	-.2633	.2715	.2693	.0719	.3334	-.1953	.1728	.0381	1.0000						
10 MANUFACTURING COSTS	-.0101	.0133	.0181	.1555	.1850	-.0451	.3825	.1249	.6982	1.0000					
11 NUMBER OF BIDDERS	.0950	-.0880	-.0958	.2195	-.0359	-.3271	.6303	.1661	-.1028	.1159	1.0000				
12 FIBER	-.1015	.0935	.1026	-.1150	.1659	.0238	.2857	-.0386	.5980	.5723	-.0799	1.0000			
13 SELLING VALUE	-.3597	.3627	.3590	.1026	.2859	.1459	.1782	.1906	.8140	.7987	-.1456	.5640	1.0000		
14 COMPETITIVE STATUS	.1287	-.1220	-.1370	.0915	-.0973	-.0714	.0254	.1514	-.0791	-.0012	.0931	-.0955	-.0736	1.0000	
15 TERMINATION PERIOD	.0419	-.0473	-.0372	-.1001	.0718	.1995	-.1473	-.1597	.0590	-.0603	-.2568	.1534	.0344	-.7620	1.0000

TABLE 61--CORRELATION COEFFICIENTS FOR REGION 6 ZONE 1

SALE CHARACTERISTICS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 VOLUME/ACRE	1.0000														
2 SALVAGE STATUS	-.9985	1.0000													
3 SET-ASIDE STATUS	-.9986	.9968	1.0000												
4 SALE VOLUME	.1975	-.1740	-.1978	1.0000											
5 MAJOR SPECIES	-.3333	.3275	.3371	.1420	1.0000										
6 APPRAISED STUMPAGE	.0405	-.0444	-.0410	-.0443	.3318	1.0000									
7 OVERBID	.2595	-.2591	-.2626	.0850	-.0299	-.0374	1.0000								
8 ROAD COSTS	.0839	-.0599	-.0885	.4573	-.0281	-.1999	.0023	1.0000							
9 LOGGING COSTS	-.1583	.1612	.1618	-.0443	-.2048	-.4480	-.1823	.0462	1.0000						
10 MANUFACTURING COSTS	.1121	-.1110	-.1159	.1135	.0736	-.1606	.1126	.1123	.2066	1.0000					
11 NUMBER OF BIDDERS	.3520	-.3531	-.3613	.1065	-.1382	-.0542	.6236	.1145	-.1825	.1673	1.0000				
12 FIBER	-.0339	.0197	.0338	-.1179	-.0949	-.0600	-.0006	-.1044	-.1078	-.3058	.0232	1.0000			
13 SELLING VALUE	-.3160	.3199	.3135	.0437	.4088	.5793	-.1191	.0863	.1172	.4415	-.1134	-.2704	1.0000		
14 COMPETITIVE STATUS	-.0131	.0216	.0021	.0114	-.0090	-.1365	-.0788	.0965	.0268	.1081	.0266	-.0917	.0122	1.0000	
15 TERMINATION PERIOD	-.0372	.0315	.0437	-.0195	-.0068	.2677	-.0686	-.0578	-.0035	-.2302	-.1029	.0487	.0934	-.7322	1.0000

TABLE 62--CORRELATION COEFFICIENTS FOR REGION 6 ZONE 2

SALE CHARACTERISTICS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 VOLUME/ACRE	1.0000														
2 SALVAGE STATUS	-.9998	1.0000													
3 SET-ASIDE STATUS	-.9998	.9995	1.0000												
4 SALE VOLUME	.3501	-.3420	-.3522	1.0000											
5 MAJOR SPECIES	-.0841	.0847	.0832	-.0093	1.0000										
6 APPRAISED STUMPAGE	.0874	-.0867	-.0879	-.1227	.2255	1.0000									
7 OVERBID	.1273	-.1223	-.1257	.2528	.1090	.0821	1.0000								
8 ROAD COSTS	.1563	-.1476	-.1587	.4213	.0983	-.3581	.1287	1.0000							
9 LOGGING COSTS	-.3533	.3520	.3542	-.2194	.1066	-.3411	.0011	-.1058	1.0000						
10 MANUFACTURING COSTS	-.0750	.0763	.0751	.0429	.4759	.0533	.1831	.0733	.1352	1.0000					
11 NUMBER OF BIDDERS	.2184	-.2134	-.2185	.4651	.0269	-.0624	.4747	.2772	-.2749	.1359	1.0000				
12 FIBER	.0466	-.0498	-.0460	.0078	-.2558	-.1665	-.0996	-.0777	-.2318	-.2440	.0094	1.0000			
13 SELLING VALUE	-.6776	.6785	.6768	-.2693	.4366	.4215	.0835	-.0979	.3978	.4684	-.1643	-.3403	1.0000		
14 COMPETITIVE STATUS	.0471	-.0458	-.0501	.0700	.0052	.0118	-.0424	.1110	-.0357	-.1268	.0317	.0016	-.0337	1.0000	
15 TERMINATION PERIOD	-.0540	.0529	.0543	-.0735	-.0232	.1327	-.0250	-.1131	.0258	.0240	-.1026	.0119	.1036	-.7550	1.0000

APPENDIX 3. THE USE OF THE CHOW TEST FOR STRUCTURAL SHIFTS

A procedure proposed by Chow (1960) was used to test whether a ructural shift had taken place in the relationship between overbid and rious sale characteristics. The Chow test was selected because the mber of independent variables exceeds the number of observations in the cond data set. Using Johnston's (1972) interpretation of the ocedure, I fitted equation 3 to the first n observations using linear gression and computed the residual sum of squares ($e_1'e_1$). Then e n+m sample observations were pooled and a second least squares gression was fitted. The residual sum of squares ($e'e$) was computed r the second regression. The test of the null hypothesis--that the m ditional observations obey the same relation as the first--is given by e equation,

$$F = ((e'e - e_1'e_1)/m)/(e_1'e_1/(n - k)); \tag{8}$$

ere k is the number of independent variables in the linear regression uation. The test statistic follows the F distribution with (m, n-k) grees of freedom.

The appropriate test values for the various regions and zones are as llows:

gion	Zone	n	$e_1'e_1$	m	n+m	e'e	k	n-k	Computed F	Test value
5	1	24	1,106	12	36	1,720	14	10	0.463	2.76
6	1	24	357	12	36	639	14	10	.658	2.76
1	2	24	125	12	36	438	14	10	2.090	2.76
5	2	22	283	9	31	986	14	8	2.208	2.85
6	2	24	356	12	36	786	14	10	1.006	2.76
5	3	22	664	12	34	2,101	14	8	1.443	2.76

APPENDIX 4. PROCEDURE FOR TESTING THE HYPOTHESIS THAT THERE IS NO DIFFERENCE BETWEEN SET-ASIDE AND OPEN SALES

Discriminant analysis was used in a manner analogous to a one-way multivariate analysis of variance. The U-statistic (Kramer 1972) was used as the appropriate test statistic. In this case, discriminant analysis is used to study the differences in the two groups of sales as expressed by the linear combination of sale characteristics. The estimated coefficients for each sale characteristic can be interpreted as weights in the same way that the coefficients are in multiple regression. In this respect, they serve to identify the variables that contribute most to differentiation between the two groups.

As described in the text, discriminant analysis assumes independence among explanatory variables. In practice, the technique is very robust, and the assumption of independence need not be strongly adhered to.

In the case of testing for differences between characteristics of set-aside and open sales, most of the possible explanatory variables are sufficiently independent, with the exception of appraised stumpage price. This variable is computed as a combination of the selling value and cost components determined for each sale. As such, the correlation coefficients between appraised stumpage and the components are relatively high. A possible solution would be to drop appraised stumpage price as a sale characteristic, but it was retained since it is a relatively insignificant variable in terms of the discriminant functions.

The discriminant functions are shown in the following tabulation where Z_1 is the function for set-aside sales and Z_2 is the function for open sales.

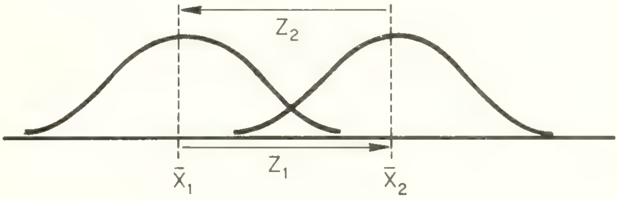
The discriminant functions were computed by a stepwise procedure, in which the variables that enter are those with the largest F values. A variable is deleted if the F value becomes too low (0.01). The U-statistic was computed for each discriminant function, and the null hypothesis is rejected if the sample U is less than the test value.

	Region 1 Zone 2		Region 5 Zone 1		Region 5 Zone 2	
	Z_1	Z_2	Z_1	Z_2	Z_1	Z_2
Volume per acre	0.618	0.590	-0.099	-0.135	-0.520	-0.507
Salvage status	9.460	9.709	16.934	17.713	6.595	6.430
Volume	-.170	-.050	-.080	.100	-.680	-.480
Major species	.022	.028	-.035	-.062		
Appraised stumpage	.067	.045	-.074	-.016	-.012	-.140
Road costs	.017	-.026	-.220	-.195	-.547	-.519
Haul distance	.035	.042	.093	.100	-.001	.009
Logging cost	.406	.384	.103	.178	-.017	.049
Manufacturing cost	.898	.888	.526	.473	.884	.921
Fiber						
Selling value	.113	.143	.257	.216	.309	.236
Termination period	-.173	-.536	.124	-.747	3.746	2.619
Constant	48.058	-49.408	-42.246	-38.353	-43.366	-37.582
U-statistic	.939		.874		.719	
Test U-statistic	.952		.930		.850	

	Region 5 Zone 3		Region 6 Zone 1		Region 6 Zone 2	
	Z_1	Z_2	Z_1	Z_2	Z_1	Z_2
Volume per acre	0.020	0.013	0.128	0.151	0.077	0.083
Salvage status	10.553	11.064			8.480	8.236
Volume	-.140	-.050	-.560	-.440	-.320	-.300
Major species	-.049	-.039	-.005	-.024	-.059	-.064
Appraised stumpage	.261	.314	.178	.162	-.308	-.323
Road costs	.057	.129			-.377	-.405
Haul distance	.038	.052	.128	.121	.065	.052
Logging cost	.238	.310	.446	.496		
Manufacturing cost	.289	.280	.587	.528	.080	.084
Fiber			.291	.279	.367	.368
Selling value	-.125	-.156	.089	.091	.512	.518
Termination period	.032	.769	2.825	2.198	1.316	1.075
Constant	-14.512	-14.207	-36.577	-34.279	-45.961	-44.730
U-statistic	.907		.878		.950	
Test U-statistic	.899		.965		.984	

APPENDIX 5. THE USE OF DISCRIMINANT FUNCTIONS TO MONITOR SALES

Discriminant functions were estimated for both competitive and noncom- titive sales. The definition of competitive sales was given in the ction, "Definitions and Available Data." The objective was to estimate nctions that combined various physical and cost characteristics observed each sale and were effective in distinguishing between competitive and ncompetitive sales. The basic problem can be visualized as studying the tent to which different populations overlap one another or diverge from e another. For example, visualize two slightly overlapping populations own as follows:



this case, the leftmost population will represent noncompetitive les, the rightmost competitive sales. Given that the sales have been assified a priori, a linear function (the discriminant function) is stimated for each population which measures the distance (Z) between the o population means ($\bar{X}$). These equations are:

$$Z_1 = \gamma_{11} + \sum_{i=2}^{n} \gamma_{1i} X_{1i-1}; \tag{9}$$

$$Z_2 = \gamma_{21} + \sum_{i=2}^{n} \gamma_{2i} X_{2i-1}; \tag{10}$$

here

Z is the distance between population means,
γ_{j1} is the intercept term for the j^{th} population, and
γ_{ji} is the coefficient for population characteristic X_i of the
th population.

The estimated discriminant functions are then used to classify all ales as either competitive or noncompetitive, regardless of the a priori assification, based on the characteristics of each sale. The classifi- ation procedure is relatively straightforward. For each sale, the Z alues are computed using each discriminant function. In this case, if 1 is greater than Z_2, then the sale is classified as having the aracteristics of a noncompetitive sale. Reverse the sequence and the ale is classified as competitive in the sense that the characteristics the particular sale are similar to sales comprising the population of ompetitive sales.

The estimated discriminant functions are shown in the following abulation on the next page.

Sale characteristics	Region 1 Zone 2		Region 5 Zone 1		Region 5 Zone 2	
	Z_1	Z_2	Z_1	Z_2	Z_1	Z_2
Volume per acre (MBF)	0.62129	0.68173	0.03855	-0.05611	-0.53047	-0.60492
Salvage status	9.74950	9.29289	18.75354	17.06144	8.07441	4.49807
SBA status	16.36478	16.83769	31.84067	30.24422	20.55825	18.56831
Sales volume (MBF)	-.00021	-.00025	-.00022	-.00030	-.00079	-.00103
Major species (percent)	.05937	.04451	.01392	-.01590	.13359	.15224
Appraised stumpage ($/MBF)	.12634	.10785	.05310	-.08453	.01397	-.32176
Overbid ($/MBF)	-.38765	-.25130	-.03981	-.00457	-.12257	-.06231
Road costs ($/MBF)	.17043	.11196	.01209	-.18101	-.66490	-.91749
Haul distance (miles)	.00437	.00989	.06897	.08848	-.00107	-.00743
Logging costs ($/MBF)	.52111	.49631	.15571	.05444	-.06196	-.25358
Manufacturing costs ($/MBF)	1.00665	.93885	.78909	.59930	.75846	.51419
Number of bidders	2.27453	2.75349	-.12405	.46883	.97747	1.62718
Fiber (percent)	.23055	.24514	.30550	.29236	-.04567	-.05566
Selling value ($/MBF)	.14722	.21308	.14656	.27385	.44824	.72447
Termination period (years)	-.62457	-.67182	.25745	.78312	3.84303	4.83871
Constant	-72.60328	-77.10054	-76.56212	-71.76233	-67.65229	-67.11818

Sale characteristics	Region 5 Zone 3		Region 6 Zone 1		Region 6 Zone 2	
	Z_1	Z_2	Z_1	Z_2	Z_1	Z_2
Volume per acre (MBF)	0.08755	0.01696	-0.17221	-0.22432	0.07460	0.07622
Salvage status	14.36894	9.04530	15.16427	14.98504	10.37391	9.40501
SBA status	21.30913	21.57700	16.65939	16.32758	13.90379	12.92309
Sales volume (MBF)	-.00008	-.00023	-.00055	-.00059	-.00024	-.00039
Major species (percent)	-.07368	-.05615	-.00336	-.00530	-.03476	-.04852
Appraised stumpage ($/MBF)	.42069	.27744	.10329	.09394	.33077	.32174
Overbid ($/MBF)	-.12051	-.04478	-.03412	.05540	-.14001	-.10920
Road costs ($/MBF)	.29099	.04602	-.30428	-.33174	.23396	.21608
Haul distance (miles)	.03197	.02931	.20050	.20659	.08846	.09654
Logging costs ($/MBF)	.46477	.28304	.34772	.33246	.64652	.61374
Manufacturing costs ($/MBF)	.37317	2.29143	.45548	.42587	.53529	.59225
Number of bidders	.58689	.91873	1.07349	1.63944	.56231	1.00864
Fiber (Percent)	-.15713	-.18169	[1]	[1]	.35083	.35360
Selling value ($/MBF)	-.20298	-.09187	.12466	.14836	[1]	[1]
Termination period (years)	-1.32466	.41886	1.05823	1.21181	.84711	1.28949
Constant	-42.93132	-37.66939	-57.52810	-59.56042	-59.26485	-59.77977

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[1] This variable was deleted because its impact on the sum of squares was insufficient.

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Effects of Different Sources of Fertilizer Nitrogen on Growth and Nutrition of Western Hemlock Seedlings

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English Equivalents

1 liter = 0.2642 gallon
1 kilogram = 2.2046 pound
1 gram = 0.0353 ounce
1 centimeter = 0.3937 inch
1 kilogram per hectare = 1.1206 pounds per acre
$(9/5^{\circ}C) + 32 = {}^{\circ}F$

EFFECTS OF DIFFERENT SOURCES OF FERTILIZER NITROGEN ON GROWTH AND NUTRITION OF WESTERN HEMLOCK

Reference Abstract

Radwan, M. A., and Dean S. DeBell.
1980. Effects of different sources of fertilizer nitrogen on growth and nutrition of western hemlock seedlings. USDA For. Serv. Res. Pap. PNW-267, 15 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Twelve different nitrogen (N) fertilizer treatments were tested on potted western hemlock (Tsuga heterophylla (Raf.) Sarg.) seedlings. Fertilizers affected soil N and pH, and growth and foliar chemical composition of seedlings. Urea plus N-Serve and sulfur-coated urea appear more promising for promoting growth than other fertilizers tested. Results, however, do not explain reported variability in response of hemlock stands to N fertilization.

Keywords: Nitrogen fertilizer response, seedling growth, western hemlock, Tsuga heterophylla.

RESEARCH SUMMARY

Research Paper PNW-267

1980

The following fertilization treatments were applied in the spring to potted, 4-year-old western hemlock (Tsuga heterophylla (Raf.) Sarg.) seedlings: untreated control, ammonium nitrate, ammonium sulfate, ammonium sulfate plus N-Serve, ammonium sulfate plus calcium sulfate, calcium nitrate, sulfur-coated urea, urea, urea plus N-Serve, urea-ammonium sulfate, urea plus calcium sulfate, urea-gypsum, urea-ammonium polyphosphate. Application rates were equivalent to 224 and 448 kilograms of nitrogen (N) per hectare, and seedlings were harvested 3 and 8 months after treatment. Soil pH varied by treatment, and most urea fertilizers caused a substantial initial rise. Fertilizers were nitrified in the soil, and N-Serve was an effective nitrification inhibitor. Seedling growth was considerably more with fertilizer than without, but most differences between fertilized and unfertilized seedlings were not significant; differences between treatments were small, although urea plus N-Serve and sulfur-coated urea appear more promising. Fertilization greatly increased the level of chlorophyll and more than doubled total N content in the foliage. Foliage from the different fertilization treatments contained similar levels of total N, and

concentrations of the soluble N fractions were always small. Total N in foliage was significantly correlated with nitrate N of the soil and with total chlorophyll. Moreover, foliar concentrations of the macroelements and microelements determined were, in general, either depressed or unaffected by fertilizer. Results suggest that the source of N does not account for reported variability in response of natural stands of western hemlock to N fertilization, although field tests with some N sources are warranted.

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INTRODUCTION

Growth responses of natural stands of western hemlock (*Tsuga heterophylla* Raf.) Sarg.) to nitrogen (N) fertilization have been extremely variable. esponses reported so far range from increases of 50 percent or more to aparent reductions of about 20 percent. Generally, N fertilization has been ore successful in stands located on the lowlands west of Puget Sound and n the west slopes of the Cascade Range than in forests of coastal Oregon nd Washington where N fertilization is now believed unprofitable (DeBell t al. 1975, Webster et al. 1976).

Many factors may be responsible for variation in response of trees to N ertilization. The form of N applied may be a significant factor; it has een known to affect both growth and chemical composition of conifers other han western hemlock (Pharis et al. 1964, McFee and Stone 1968, Radwan t al. 1971, Christersson 1972, Van den Driessche and Dangerfield 1975).

Information on effects of N sources on western hemlock is very limited nd generally suggests that the species favors ammonium nitrogen (Taylor 935, Swan 1960, Krajina et al. 1973) or a mixture of ammonium and nitrate itrogen (Van den Driessche 1971, Krajina et al. 1973). This information oes not explain causes of variation in response under field conditions to mmonium fertilizers or to urea which is very rapidly hydrolyzed to amonium carbonate in most soils. Furthermore, the literature contains no ata on effects of the different formulations of urea or nitrification nhibitors.

In this study, we evaluated 12 fertilizer treatments on western hemlock eedlings potted in uniform, light soil. We applied the test treatments at wo rates and determined effects of the fertilizers on soil and seedlings.

MATERIALS AND METHODS

Test seedlings.--In February 1976, 2-1 western hemlock seedlings from a ow elevation Washington seed source were individually potted in 7.6-liter lastic pots. Each pot contained about 6 kg of Tumwater sandy loam soil, nd the seedlings were allowed to get established in the pots through the 976 growing season. In March 1977, 1 month before treatment, seedlings ere watered with half-strength Hoagland's nutrient solution lacking N Hoagland and Arnon 1950). In April 1977, the height and diameter of the eedlings were measured prior to treatment. Seedlings were then numbered nd assigned at random to receive the different treatments. There were 10 ots per treatment: two for measurements of pH, four for a seedling harvest in August 1977, and four for a final harvest in January 1978. Seedlings were kept under a shaded, roofed shelter to avoid leaching of fertilizer by rain.

Fertilization treatments.--There were 12 fertilization treatments and an unfertilized control:

1. Ammonium nitrate, commercial fertilizer, 34 percent N.
2. Ammonium sulfate, commercial fertilizer, 21 percent N, 24 percent sulfur (S).
3. Ammonium sulfate (same as No. 2) plus N-Serve.[1]
4. Ammonium sulfate (same as No. 2) plus calcium sulfate.[2]
5. Calcium nitrate, commercial fertilizer, 15.5 percent N, 22 percent calcium (Ca).
6. Sulfur-coated urea, from Tennessee Valley Authority (TVA), Alabama, 35.9 percent N, 17.5 percent S.
7. Urea, commercial fertilizer, 46 percent N.
8. Urea (same as No. 7) plus N-Serve.
9. Urea-ammonium sulfate, from TVA, Alabama, 40.8 percent N, 4.5 percent S.
10. Urea (same as No. 7) plus calcium sulfate.
11. Urea-gypsum, from Union Oil Company, California, 34 percent N, 10 percent S.
12. Urea-ammonium polyphosphate, from TVA, Alabama, 35 percent N, 17.8 percent P_2O_5.

Treatments were applied at two rates equivalent to 224 and 448 kg N/ha. N-Serve was mixed with the fertilizer before application at rates of 1.12 and 2.24 kg/ha for the low- and high-rate treatments. Fertilizers were mixed with the top 2 cm of soil, and pots were watered the same day. Treatments were applied April 22, 1977; throughout the 1977 growing season, seedlings were watered as needed without wetting the foliage or leaching of soil solution.

Soil pH measurements.--Two pots of each treatment were used to determine pH during the first 2 months after fertilizer application. Soil was obtained from the pots with a sampling tube to a depth of 7.6 cm after removal of visible undissolved fertilizer from the surface and with minimum disturbance to the seedlings. Determinations were made on May 2, May 12, and June 30, 1977; soils were returned to their respective pots after measurement. Soil for two additional measurements of pH were obtained from the other pots used for the first (August 1, 1977) and second (January 3, 1978) seedling harvests, after seedlings were lifted and soils were composited as outlined below. On the five sampling dates, soil was thoroughly mixed with distilled water (1:1) and pH was measured with glass electrode after the suspension had been stirred with a magnetic stirrer for 15 minutes.

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[1] A nitrification inhibitor produced by the Dow Chemical Company. Active ingredient is 2-chloro-6-(trichloromethyl)pyridine. Mention of companies and products does not constitute an endorsement by the U.S. Department of Agriculture.

[2] $CaSO_4.2H_2O$ added in amounts containing Ca equivalent to that in the calcium nitrate treatment.

Growth measurements.--For the first harvest, four pots were chosen at andom from the eight pots not used for the first three pH measurements. he remaining four pots were used for the second harvest. In each case, eight and diameter of the seedlings were determined. Representative amples of current year's needles were taken from the seedlings for hemical analysis as outlined below. Seedlings were then lifted and evered at the root collar. Shoots were dried at 65°C to constant weight n a forced-air oven. Dry weights of needles taken for chemical analysis were added to weights of the corresponding seedling shoots to obtain dry weight of shoots.

Sampling and processing of foliage.--Sampling was limited to fully expanded current year's needles. Ten-gram fresh needle samples were taken from each seedling. Needles were obtained from all parts of the seedlings, and samples of each two seedlings of each treatment were pooled to produce composite samples of 20 g. There were two composite samples per treatment in each harvest. From these samples, fresh subsamples were taken to determine moisture, chlorophyll, and some nitrogen fractions. Remaining tissue was dried to constant weight at 65°C, ground to 40 mesh in a Wiley mill, and stored in sealed containers at -15°C until needed for determination of total N in the first harvest, and estimation of total N, phosphorus (P), potassium (K), Ca, magnesium (Mg), S, manganese (Mn), iron (Fe), zinc (Zn), and copper (Cu), in the second harvest.

Soil sampling and processing.--After seedlings had been lifted, soil from each two pots of each treatment were pooled into two composite samples per treatment. Soil of the composite samples was thoroughly mixed and passed through a 2-mm sieve. Subsamples of the sieved soil were then taken for determination of pH (see above), moisture, ammonium nitrogen, and nitrate nitrogen.

Chemical analysis of foliage.--Moisture content of the needles was determined by drying to constant weight at 65°C. Needles for determination of nitrogen fractions were extracted in a homogenizer with ethanol at a final concentration of 70 percent, and homogenate was centrifuged. The clear solution containing the alcohol-soluble components was extracted with chloroform, and the organic layer containing the lipids and chlorophylls was separated and discarded. Remaining aqueous solution was filtered and completed to volume with distilled water. The aqueous solution was used to determine total soluble N by the standard micro-Kjeldahl procedure, ammonium and nitrate nitrogen according to Bremner (1965) and amide N by the method of Pucher et al. (1935).

Total N (including nitrate) in the ovendry needles was determined by the standard micro-Kjeldahl procedure.

The chlorophylls (a and b) were extracted from the fresh needles with 80-percent acetone. Optical densities of the extracts were measured at 663 and 645 nm in a spectrophotometer, and contents were computed by Arnon's (1949) equations derived from MacKinney's (1941) absorbancy index values.

Minerals were determined in foliage of seedlings from the second harvest only. Analyses were on the dry needles or on solutions of the tissue's ash as follows: P by the molybdenum blue technique (Chapman and Pratt 1961); total S by a turbidimetric method (Butters and Chenery 1959); and K, Ca, Mg, Mn, Fe, Zn, and Cu by standard atomic absorption spectrophotometric techniques (Perkin-Elmer Corporation 1976).

Soil analyses.--Moisture was determined by drying the fresh samples to constant weight at 105°C. Fresh soil samples were extracted with 2N KCl. Ammonium and nitrate nitrogen in the extracts were determined by semimicro-Kjeldahl procedure and steam distillation as described by Bremner (1965).

Statistical analyses.--Data were subjected to analysis of variance, after arc-sine transformation when necessary, and means were compared according to Tukey's test. Correlation coefficients (r) between some variables were also calculated (Snedecor 1961).

RESULTS

In both harvests, trends of measured parameters for the low and high rates of fertilizer application were similar. For simplicity, therefore, we will present only the data pertaining to the low application rate (224 kg N/ha), the rate most commonly used for forest fertilization in the Pacific Northwest. Also, in presenting the data, we will used the 5-percent probability level ($P < 0.05$) to judge statistical significance of differences among treatments.

Soil pH.--Changes in soil pH after treatment are shown in table 1. In the first two pH measurements, 10 and 20 days after treatment, fertilizers varied greatly in their effect on soil reaction. Urea, urea plus N-Serve, urea-ammonium polyphosphate, and urea-ammonium sulfate significantly increased the pH; all other fertilizers also affected pH, but values were not statistically different from pH of the untreated control. By June 30, all treatments were significantly different from the control--pH was higher with urea plus N-Serve and lower with remaining treatments. Subsequently, through the first and second harvests, soil of all treatments became lower in pH than that of the control. In August, however, only seven treatments varied significantly from the control; by the following January, only the ammonium sulfate treatment was significantly different.

Soil ammonium and nitrate nitrogen.--After the first harvest, ammonium and nitrate N in soil varied significantly among treatments, and the untreated soil contained the lowest levels (table 2). The two treatments containing N-Serve resulted in the highest ammonium concentrations, indicating effectiveness of the compound as a nitrification inhibitor. All ammonium- and urea-containing fertilizers were nitrified in the soil, and, except for the urea plus N-Serve treatment, levels of nitrates exceeded those of ammonium.

Table 1--Effect of nitrogen fertilizers on soil pH[1]

Treatment	Measurement date				
	May 2, 1977	May 12, 1977	June 30, 1977	August 1, 1977	January 3, 1978
Untreated control	6.00 def	5.98 cde	6.00 b	5.92 a	5.58 a
Ammonium nitrate	5.75 ef	5.20 e	4.90 c-f	4.96 bc	4.95 ab
Ammonium sulfate	5.44 f	5.28 de	4.60 efg	5.20 abc	4.58 b
Ammonium sulfate + N-Serve[2]	5.55 ef	5.45 de	5.35 c	4.86 bc	4.65 ab
Ammonium sulfate + calcium sulfate	5.58 ef	5.45 de	4.70 d-g	4.75 c	4.78 ab
Calcium nitrate	5.55 ef	5.43 de	5.30 cd	5.12 bc	5.40 ab
Sulfur-coated urea	6.46 cde	6.33 bcd	5.05 cde	5.42 abc	5.55 a
Urea	8.00 a	7.60 a	4.85 c-f	5.36 abc	5.20 ab
Urea + N-Serve[2]	8.10 a	7.33 ab	6.85 a	5.50 ab	5.40 ab
Urea-ammonium sulfate	7.35 abc	7.60 a	4.65 efg	5.02 bc	5.32 ab
Urea + calcium sulfate	6.74 bcd	6.30 bcd	5.15 cde	5.00 bc	5.25 ab
Urea-gypsum	6.75 bcd	6.75 abc	4.40 fg	5.05 bc	5.40 ab
Urea-ammonium polyphosphate	7.69 ab	7.23 ab	4.20 g	4.92 bc	5.45 ab

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[1] Values are averages of 2 measurements per treatment. Values in the same vertical column followed by the same letter(s) are not statistically different ($P < 0.05$).

[2] N-Serve is a nitrification inhibitor. Active ingredient is 2-chloro-6(trichloromethyl)pyridine.

By the second harvest, ammonium levels had decreased with all fertilizers because of nitrification and uptake by the seedlings; however, ammonium was still relatively high in soils treated with fertilizers containing N-Serve. With most fertilizers, nitrates were generally lower than in August primarily because of uptake by plants, but in all treatments, levels were still higher than those of ammonium.

Table 2--Effect of nitrogen fertilization on soil ammonium and nitrate nitrogen[1]

Treatment	1st harvest		2d harvest	
	Ammonium nitrogen	Nitrate nitrogen	Ammonium nitrogen	Nitrate nitrogen
		Parts per million		
Untreated control	0.4 e	0.6 d	0.4 b	0.7 e
Ammonium nitrate	3.4 d	33.2 ab	.4 b	36.7 a
Ammonium sulfate	6.2 bc	26.2 ab	.3 b	20.0 abc
Ammonium sulfate + N-Serve[2]	18.2 a	25.8 ab	4.6 a	25.8 ab
Ammonium sulfate + calcium sulfate	4.1 cd	31.6 ab	.6 b	27.6 ab
Calcium nitrate	.9 e	38.3 a	.4 b	33.4 a
Sulfur-coated urea	.9 e	18.0 b	.7 b	5.9 de
Urea	.7 e	15.6 bc	.3 b	7.6 cd
Urea + N-Serve[2]	9.3 b	5.4 cd	2.0 ab	6.2 de
Urea-ammonium sulfate	.9 e	25.4 ab	.3 b	18.2 a-d
Urea + calcium sulfate	1.3 e	27.4 ab	.4 b	10.0 cd
Urea-gypsum	.7 e	16.2 bc	.6 b	6.6 de
Urea-ammonium polyphosphate	.8 e	26.7 ab	.6 b	14.3 bcd

[1] Values are averages of 2 composite soil samples each. Values in the same vertical column followed by the same letter(s) are not statistically different ($P < 0.05$).

[2] N-Serve is a nitrification inhibitor. Active ingredient is 2-chloro-6(trichloromethyl)pyridine.

Growth characteristics.--Dry weight of seedling shoots from the first harvest ranged from 23.5 g for sulfur-coated urea to 48.8 g for ammonium nitrate (table 3). Second-harvest plants varied from 26.1 g for the control to 58.9 g for the urea-ammonium sulfate. In both harvests, however, there were no significant differences among treatments because of large variations within treatments.

Height growth of seedlings of the first harvest ranged from 14.6 percent for ammonium sulfate plus calcium sulfate and urea-ammonium sulfate to 21.4 percent for urea plus N-Serve; it did not vary significantly among treatments. Percent height growth in the second harvest, however, was significantly higher for urea plus N-Serve (53.9 percent) and sulfur-coated urea (49.3 percent) than for the control seedlings (13.8 percent).

Table 3--Growth characteristics of western hemlock seedlings[1]

Treatment	1st harvest			2d harvest		
	Shoot dry weight	Height growth	Diameter growth	Shoot dry weight	Height growth	Diameter growth
	Grams	- - - Percent - - -		Grams	- - - Percent - - -	
Untreated control	30.2 a	16.9 a	5.0 a	26.1 a	13.8 b	7.8 b
Ammonium nitrate	48.8 a	20.0 a	6.7 a	39.8 a	31.5 ab	26.9 ab
Ammonium sulfate	35.0 a	20.7 a	8.6 a	53.8 a	32.4 ab	28.1 ab
Ammonium sulfate + N-Serve[2]	40.0 a	17.4 a	3.1 a	41.6 a	35.2 ab	30.1 ab
Ammonium sulfate + calcium sulfate	42.5 a	14.6 a	4.3 a	46.8 a	34.7 ab	25.0 ab
Calcium nitrate	40.2 a	14.8 a	3.5 a	57.1 a	33.3 ab	25.7 ab
Sulfur-coated urea	23.5 a	18.2 a	10.5 a	48.5 a	49.3 a	58.3 a
Urea	40.2 a	17.4 a	2.4 a	50.8 a	33.3 ab	24.9 ab
Urea + N-Serve[2]	28.2 a	21.4 a	9.9 a	51.2 a	53.9 a	31.2 ab
Urea-ammonium sulfate	40.8 a	14.6 a	24.6 a	58.9 a	46.6 ab	26.9 ab
Urea + calcium sulfate	34.0 a	17.3 a	7.7 a	55.1 a	20.4 ab	23.2 b
Urea-gypsum	39.8 a	15.6 a	10.4 a	51.0 a	29.1 ab	35.1 ab
Urea-ammonium polyphosphate	29.8 a	18.8 a	9.5 a	43.1 a	32.7 ab	18.6 b

[1] Values are averages of 4 seedlings each. Values in the same verticle column followed by the same letter(s) are not statistically different ($P < 0.05$).

[2] N-Serve is a nitrification inhibitor. Active ingredient is 2-chloro-6(trichloromethyl)pyridine.

Diameter growth of seedlings did not vary significantly among treatments of the first harvest; it ranged from 2.4 percent for urea to 24.6 percent for urea-ammonium sulfate. In the second harvest, sulfur-coated urea produced diameter growth (58.3 percent) significantly higher than that of control seedlings (7.8 percent) and of seedlings treated with urea plus calcium sulfate (23.2 percent) and urea-ammonium polyphosphate (18.6 percent).

Foliar nitrogen.--Total N of the needles from the first harvest varied little among fertilizer treatments; it averaged 1.50 percent and was significantly higher than levels in the control seedlings at 0.58 percent (table 4). By the second harvest, average total N for the fertilizer treatments (1.32 percent) was somewhat lower than before--probably because of dilution by growth; total N was still significantly higher in all treated seedlings than in the control. Also, total N content of the needles was significantly correlated with nitrate N of the soil in the first (r=0.75) and second (r=0.48) harvests.

Table 4--Concentrations of different nitrogen fractions in foliage of western hemlock seedlings[1]

Treatment	1st harvest					2d harvest				
	Total nitrogen	Ammonium nitrogen	Nitrate nitrogen	Amide nitrogen	Total soluble nitrogen	Total nitrogen	Ammonium nitrogen	Nitrate nitrogen	Amide nitrogen	Total soluble nitrogen
	Percent	- - Parts per million - -			Percent	Percent	- - Parts per million - -			Percent
Untreated control	0.58 b	11 f	18 a	49 b	0.04 f	0.58 b	16 ab	14 b	39 a	0.04 c
Ammonium nitrate	1.61 a	162 a	6 a	69 ab	.26 a	1.42 a	22 ab	22 ab	61 a	.12 a
Ammonium sulfate	1.53 a	108 d	9 a	76 ab	.14 de	1.39 a	13 b	25 a	67 a	.06 c
Ammonium sulfate + N-Serve[2]	1.48 a	146 ab	24 a	123 ab	.12 e	1.41 a	19 ab	25 a	58 a	.08 abc
Ammonium sulfate + calcium sulfate	1.56 a	140 abc	15 a	113 ab	.17 cd	1.34 a	18 ab	16 ab	53 a	.04 c
Calcium nitrate	1.55 a	118 bcd	23 a	156 ab	.22 ab	1.22 a	20 ab	14 ab	45 a	.08 abc
Sulfur-coated urea	1.39 a	158 a	27 a	107 ab	.14 de	1.22 a	15 ab	19 ab	39 a	.06 c
Urea	1.56 a	140 abc	20 a	129 ab	.21 b	1.34 a	15 ab	23 ab	60 a	.08 abc
Urea + N-Serve[2]	1.34 a	123 bcd	47 a	125 ab	.12 e	1.32 a	15 ab	19 ab	51 a	.06 c
Urea-ammonium sulfate	1.44 a	109 d	41 a	168 a	.14 de	1.18 a	19 ab	17 ab	37 a	.07 bc
Urea + calcium sulfate	1.50 a	69 e	23 a	115 ab	.13 e	1.30 a	23 ab	17 ab	54 a	.07 bc
Urea-gypsum	1.42 a	110 cd	11 a	67 ab	.12 e	1.24 a	17 ab	21 ab	59 a	.07 bc
Urea-ammonium polyphosphate	1.57 a	165 a	34 a	133 ab	.18 bc	1.41 a	25 a	16 ab	59 a	.08 abc

[1] Values are averages of 2 composite samples each. Values in the same vertical column followed by the same letter(s) are not statistically different ($P < 0.05$).

[2] N-Serve is a nitrification inhibitor. Active ingredient is 2-chloro-6(trichloromethyl)pyridine.

Ammonium N in the foliage varied significantly among treatments in the irst harvest. Levels were lowest in the control seedlings (11 p/m) and ighest in seedlings treated with urea-ammonium polyphosphate (165 p/m), nd concentrations were significantly correlated with nitrate N of the soil r=0.48). Levels decreased greatly by the second harvest; they ranged from 3 to 25 p/m and were significantly higher with urea-ammonium polyphosphate han with ammonium sulfate.

Foliage of the first harvest contained 6 to 47 p/m nitrate N, but there ere no significant differences among treatments. In the second harvest, owever, there were significantly higher nitrate N levels with the ammonium ulfate and ammonium sulfate plus N-Serve treatments than with the control; oliage of remaining treatments contained similar levels of nitrate N.

Average amide N was much higher in the first (110 p/m) than in the second 52 p/m) harvest. Levels of the first harvest were significantly higher ith urea-ammonium sulfate than with the control. Amide N content (37 to 7 p/m), however, did not vary significantly among treatments of the second arvest.

In the first harvest, total soluble N varied significantly among treat- ents, and the levels in foliage of all fertilized seedlings were signifi- antly higher than in the control trees. Similarly, there were significant ifferences among treatments in the second harvest, but levels of total oluble N were much lower than before. Concentrations of total soluble N n the needles were significantly correlated with nitrate N of the soil in oth the first (r=0.70) and second (r=0.52) harvests.

The chlorophylls.--In the first harvest, all fertilizers significantly ncreased levels of chlorophyll 'a' and total chlorophyll in the needles ver those in foliage of control plants (table 5). Levels of chlorophyll 'b' were also lowest in seedlings from the control, ammonium sulfate, and rea plus N-Serve treatments. Average ratio of chlorophyll 'a' to hlorophyll 'b' was 2.37.

By the second harvest, the control seedlings still contained the lowest concentrations of chlorophyll 'a', chlorophyll 'b', and total chlorophyll. Levels of chlorophyll 'b' in the control seedlings, however, did not vary significantly from levels in foliage from the ammonium sulfate plus N-Serve and calcium nitrate treatments. Also, concentrations of total chlorophyll were similar for the control and calcium nitrate treatments. Average levels of the chlorophylls decreased somewhat in the second harvest, probably as a result of dilution by growth; but average ratio of chlorophyll 'a' to chlorophyll 'b' did not change much (2.02). Total chlorophyll content was significantly correlated with total N in the needles in both the first (r=0.91) and second (r=0.85) harvests.

Table 5--Levels of chlorophyll and chlorophyll ratios in foliage of western hemlock seedlings[1]

Treatment	1st harvest				2d harvest			
	Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophyll	Chlorophyll 'a'/ chlorophyll 'b'	Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophyll	Chlorophyll 'a'/ chlorophyll 'b'
	Milligrams per gram of dry tissue							
Untreated control	1.12 b	0.54 b	1.67 b	2.06	1.44 c	0.88 b	2.31 c	1.46
Ammonium nitrate	3.62 a	1.53 a	5.15 a	2.36	2.82 ab	1.35 a	4.16 ab	2.08
Ammonium sulfate	2.84 a	1.11 ab	3.96 a	2.56	2.98 ab	1.43 a	4.40 ab	2.08
Ammonium sulfate + N-Serve[2]	3.93 a	1.72 a	5.64 a	2.29	2.72 ab	1.28 ab	4.00 ab	2.12
Ammonium sulfate + calcium sulfate	3.48 a	1.42 a	4.90 a	2.44	2.84 ab	1.35 a	4.20 ab	2.11
Calcium nitrate	3.50 a	1.50 a	5.00 a	2.34	2.20 b	1.16 ab	3.37 bc	1.91
Sulfur-coated urea	2.96 a	1.28 a	4.24 a	2.33	2.68 ab	1.33 a	4.01 ab	2.02
Urea	3.54 a	1.50 a	5.05 a	2.36	2.98 ab	1.43 a	4.41 ab	2.08
Urea + N-Serve[2]	2.94 a	1.17 ab	4.11 a	2.52	3.10 a	1.48 a	4.58 ab	2.08
Urea-ammonium sulfate	3.05 a	1.30 a	4.34 a	2.36	2.73 ab	1.38 a	4.10 ab	1.98
Urea + calcium sulfate	3.36 a	1.44 a	4.79 a	2.36	2.93 ab	1.42 a	4.34 ab	2.08
Urea-gypsum	3.40 a	1.46 a	4.86 a	2.34	3.18 a	1.52 a	4.70 a	2.08
Urea-ammonium polyphosphate	3.38 a	1.42 a	4.80 a	2.46	3.13 a	1.45 a	4.58 ab	2.16

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[1] Values are averages of 2 composite samples each. Values in the same vertical column followed by the same letter(s) are not statistically different ($P < 0.05$).

[2] N-Serve is a nitrification inhibitor. Active ingredient is 2-chloro-6(trichloromethyl)pyridine.

Macroelements other than N.--Concentration of P was significantly higher in the untreated seedlings than in foliage from all other treatments except sulfur-coated urea (table 6). Dilution by growth was probably responsible for this result.

Levels of K, Mg, and S in the foliage varied from 0.66 to 0.83 percent, 0.12 to 0.18 percent, and 0.10 to 0.12 percent, respectively. There were, however, no significant differences among treatments.

Calcium concentration was significantly higher in the control than in seedlings of all other treatments. Again, as with P, this result was probably due to dilution by growth.

Seedlings from fertilizer treatments containing P, Ca, or S were not significantly higher in concentrations of these elements than seedlings from other treatments. Apparently the untreated soil was sufficient in these elements.

Micronutrients.--Concentrations of the four microelements determined varied significantly among treatments (table 6). Highest and lowest Mn levels were in seedlings of the control (696 p/m) and sulfur-coated urea (249 p/m) treatments. Fe levels in the foliage were highest in the control (112 p/m) and lowest in seedlings treated with ammonium sulfate plus calcium sulfate (60 p/m). Fe/Mn ratios ranged from 0.10 to 0.29, but high Mn levels were not associated with reduced concentrations of Fe as was expected.

Zinc levels were significantly lower in foliage from seedlings of the control (8 p/m), urea-gypsum (10 p/m), and sulfur-coated urea (11 p/m) treatments than in foliage from the urea plus calcium sulfate seedlings (33 p/m). Copper concentrations, on the other hand, were lowest and highest in foliage from seedlings of the urea-gypsum (0.1 p/m) and urea (3.0 p/m) treatments.

Table 6--Levels of macronutrients and micronutrients in foliage of western hemlock seedlings, 2d harvest[1]

Treatment	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu
	Percent					Parts per million			
Untreated control	0.22 a	0.72 a	0.61 a	0.18 a	0.10 a	696 a	112 a	8 b	0.2
Ammonium nitrate	.12 b	.74 a	.38 b	.13 a	.10 a	436 a-d	77 ab	15 ab	1.2
Ammonium sulfate	.14 b	.83 a	.37 b	.14 a	.12 a	647 ab	69 ab	13 ab	2.0
Ammonium sulfate + N-Serve[2]	.14 b	.75 a	.33 b	.14 a	.11 a	556 abc	82 ab	12 ab	2.0
Ammonium sulfate + calcium sulfate	.12 b	.77 a	.36 b	.14 a	.12 a	590 abc	60 b	12 ab	.8
Calcium nitrate	.11 b	.67 a	.40 b	.12 a	.10 a	325 cd	65 ab	17 ab	2.0
Sulfur-coated urea	.16 ab	.73 a	.37 b	.14 a	.10 a	249 d	62 ab	11 b	.5
Urea	.14 b	.77 a	.36 b	.14 a	.10 a	368 bcd	72 ab	16 ab	3.0
Urea + N-Serve[2]	.15 b	.80 a	.34 b	.14 a	.10 a	254 d	75 ab	13 ab	1.0
Urea-ammonium sulfate	.12 b	.68 a	.34 b	.12 a	.10 a	330 cd	72 ab	19 ab	.8
Urea + calcium sulfate	.14 b	.73 a	.40 b	.14 a	.12 a	386 a-d	88 ab	33 a	1.0
Urea-gypsum	.14 b	.78 a	.30 b	.12 a	.10 a	311 cd	69 ab	10 b	.1
Urea-ammonium polyphosphate	.13 b	.66 a	.37 b	.12 a	.10 a	430 a-d	67 ab	13 ab	.8

[1] Values are averages of 2 composite samples each. Values in the same vertical column followed by the same letter(s) are not statistically different ($P < 0.05$).

[2] N-Serve is a nitrification inhibitor. Active ingredient is 2-chloro-6(trichloromethyl)pyridine.

DISCUSSION AND CONCLUSIONS

The different sources of N fertilizers affected soil pH, soil ammonium- and nitrate-N, seedling growth, and foliar chemical composition of the treated trees. For most parameters measured, however, there was much variability within treatments, indicating the need for more replication in future studies.

All fertilizers changed soil pH; initially pH was substantially increase with urea and some of the urea-containing N sources. Such effects were onl temporary, and with one exception, pH of soil from fertilizer treatments wa not significantly different from that of the untreated soil by the final harvest in January.

Fertilization increased ammonium N which was subsequently nitrified. N-Serve proved to be an effective nitrification inhibitor, but the compound should be evaluated further, especially under field conditions, before it can be recommended for use in the forest.

All fertilizer N sources tested increased seedling growth over that of the control, although most differences between fertilized and unfertilized trees were not significant. More important, there were only small differences among fertilizers in their effect on seedling growth. This indicates that western hemlock can absorb and utilize N from all fertilizers tested. Urea plus N-Serve and sulfur-coated urea, however, appear more promising than other N fertilizer sources.

Total N in the foliage increased substantially after fertilization, and concentrations were correlated with nitrate N of the soil. Foliage from the different fertilization treatments contained similar levels of total N, indicating that N from all fertilizers was equally available to the test seedlings. Ammonium-, nitrate-, and amide-N varied significantly among treatments. Levels of each of these N fractions were always small, however, and concentrations of total soluble N never exceeded 0.26 percent. Most of the N absorbed, therefore, was incorporated as proteins in the treated plants.

Fertilization increased the chlorophyll content of foliage. Average ratio of chlorophyll 'a' to chlorophyll 'b', a little over two, is similar to that found in Pinus spp. (Kramer and Kozlowski 1960). Total chlorophyll content was significantly correlated with total N in the needles. This is not surprising since N is a part of the chlorophyll molecule. Also, this correlation agrees with results obtained earlier in our laboratory with foliage from natural stands of western hemlock[3] and with recent findings in other conifers by Heinze and Fiedler (1976).

In general, foliar concentrations of the macronutrients and microelements were either depressed or not affected by fertilizer. This was probably caused by dilution effects resulting from increased growth from application of N and supplements with essential elements other than N which the test seedlings received just before treatment.

Results from this study suggest that the source of N in the fertilizer does not appear to be responsible for the reported variability in response of natural stands of western hemlock to N fertilization. It is obvious, however, that conditions under which this study was carried out vary greatly from those commonly found in the forest. Accordingly, we recommend field tests with a limited number of fertilizers before the source of N can be completely ruled out as a factor affecting response of western hemlock to N fertilization.

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[3] Radwan, M. A., and D. S. DeBell. Unpublished data on file at the Forestry Sciences Laboratory, Olympia, Wash.

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809 N.E. 6th Ave.
Portland, Oregon 97232

Radwan, M. A., and Dean S. DeBell.
1980. Effects of different sources of fertilizer nitrogen on growth and nutrition of western hemlock seedlings. USDA For. Serv. Res. Pap. PNW-267, 15 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Twelve different nitrogen (N) fertilizer treatments were tested on potted western hemlock (Tsuga heterophylla (Raf.) Sarg.) seedlings. Fertilizers affected soil N and pH, and growth and foliar chemical composition of seedlings. Urea plus N-Serve and sulfur-coated urea appear more promising for promoting growth than other fertilizers tested. Results, however, do not explain reported variability in response of hemlock stands to N fertilization.

Keywords: Nitrogen fertilizer response, seedling growth, western hemlock, Tsuga heterophylla.

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Streamflow After Patch Logging in Small Drainages Within the Bull Run Municipal Watershed, Oregon

R. Dennis Harr

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Cover photograph:
Fireweed (Epilobium angustifolum L.) growing in a clearcut in watershed FC-1 six years after logging residue was broadcast burned.

STREAMFLOW AFTER PATCH LOGGING IN SMALL DRAINAGES WITHIN THE BULL RUN MUNICIPAL WATERSHED, OREGON

Reference Abstract

Harr, R. Dennis.
1980. Streamflow after patch logging in small drainages within the Bull Run Municipal Watershed, Oregon. USDA For. Serv. Res. Pap. PNW-268, 16 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Annual water yields and size of peak flows were not changed, but low flows decreased significantly after patch logging in two small watersheds.

KEYWORDS: Streamflow -)forestry methods, logging (-hydrology, patch logging, Oregon (Bull Run Watershed)

Research Summary

Research Paper PNW-268

1980

Three experimental watersheds in the City of Portland's Bull Run Municipal Watershed were used to determine effects of patch logging on timing and quantity of streamflow. Annual water yields and size of instantaneous peak flows were not significantly changed, but low flow decreased significantly after logging of two small watersheds in small, clearcut patches totaling 25 percent of each watershed's area.

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Introduction

Changes in annual water yield, minimum streamflow, and instantaneous peak flow (the maximum rate of streamflow caused by a rain or snowmelt event) are all important in municipal watershed management. If timber cutting can increase water yield, then a municipal watershed might be made to yield more water, particularly during the summer period of low flow. Increased size of peak flows as a result of timber harvest might be associated with not only overland flow and attendant surface erosion but also erosion of stream channels. Both factors could adversely affect water quality.

In 1955, the USDA Forest Service and the City of Portland, Oregon, began a cooperative study to determine effects of timber harvest on water yield and timing of runoff and the quality of streamflow in three small watersheds within the Bull Run Municipal Watershed. This report deals only with changes in quantity and timing of streamflow.

Studies in other parts of the country have illustrated the size of increases in annual water yield after timber harvest. Results of these studies, many of which were summarized by Hibbert (1967), indicate that the size of the increase in water yield is roughly proportional to the percentage of a watershed that is clearcut. Subsequent studies in the Pacific Northwest have shown that 1st-year increases in annual water yield may be more than 50 cm in small, upland watersheds (Rothacher 1970, Harr 1976, Harris 1977, Harr et al. 1979). In absolute terms, the greatest part of each annual increase has occurred during the fall-winter rainy season, but the largest relative increases have occurred during the summer (Rothacher 1970, 1971; Harr et al. 1979).

Numerous studies throughout the United States have also described changes in the size and timing of instantaneous peak flows after logging (for example, Reinhart et al. 1963, Hewlett and Helvey 1970, Hornbeck 1973). In general, where soil disturbance had been minimal, changes in storm runoff were restricted to those seasons when reduced evapotranspiration after timber cutting caused differences in water content of the soil between logged and unlogged watersheds. Because of wetter soils at the end of the growing season, logged watersheds were hydrologically more responsive to rainfall and exhibited higher peak flows. This has caused size of peak flows in the fall to be greater the first few years after timber harvest in the Pacific Northwest (Rothacher 1973, Harr et al. 1975). As revegetation has proceeded, evapotranspiration and fall peak flows have trended toward their prelogging levels.

Some studies in the Pacific Northwest reported changes in size and timing of peak flows that appear to have been related to factors other than wetter soils caused by reduced evapotranspiration. Where soils in more than 12 percent of the total watershed area were compacted by timber harvest activities, the size of large, winter peak flows in small upland watersheds was increased 20 to 48 percent according to comparison of prelogging and postlogging relations between logged and unlogged watersheds (Harr et al. 1975, Harr et al 1979). In another study, delay and decreased size of peak flows after clearcut logging were attributed to changes in short-term snow accumulation and melt (Harr and McCorison 1979). In a watershed study in western British Columbia, soil disturbance during yarding apparently disrupted water-transmitting pores and forced water through slower routes in the soil, which caused delayed smaller peak flows after logging (Cheng et al. 1975). Taken collectively, these studies indicate size of peak flows may increase, decrease, or remain unchanged after timber harvest, depending on what part or parts of the hydrologic system are altered by timber harvest activities.

The objective of this study was to determine the effects of timber harvest on annual water yield, low flows, and instantaneous peak flows in small headwater basins in the Bull Run Municipal Watershed.

The Study

Watershed Characteristics

The study area consists of three small watersheds in the Fox Creek drainage, a tributary to the Sout Fork Bull Run River, 40 km east of Portland, Oregon (fig. 1). The watersheds, which are designated Fox Creek 1 (FC-1), Fox Creek 2 (FC-2), and Fox Creek 3 (FC-3), ar 59 ha, 253 ha, and 71 ha in size. Sideslope gradients of the watersheds average only 5-9 percent but range up to 60 percent near the watersheds' outlets. The relativel gentle topography is representativ of perhaps 25-30 percent of the Bull Run Municipal Watershed. Elevation ranges from 840 m to 1 070 m. Most soils have formed from igneous glacial till overlyin basalt and andesite, are loamy in texture with depths of 1-3 m, and exhibit moderately rapid percolati capacities. Overland flow has not been observed in the undisturbed forests of the Fox Creek Watershed Overstory vegetation is primarily old-growth Douglas-fir (*Pseudotsug menziesii* (Mirb.) Franco) and western hemlock (*Tsuga heterophyll* (Raf.) Sarg.) mixed with younger Pacific silver fir (*Abies amabilis* (Dougl.) Forbes).

Since precipitation measurements began in 1957, annual precipitatio has averaged 273 cm at the elevati of the watershed outlets, about 83 percent of which has fallen during the October-April period (fig. 2). Annual snowpack, which varies greatly from year to year,

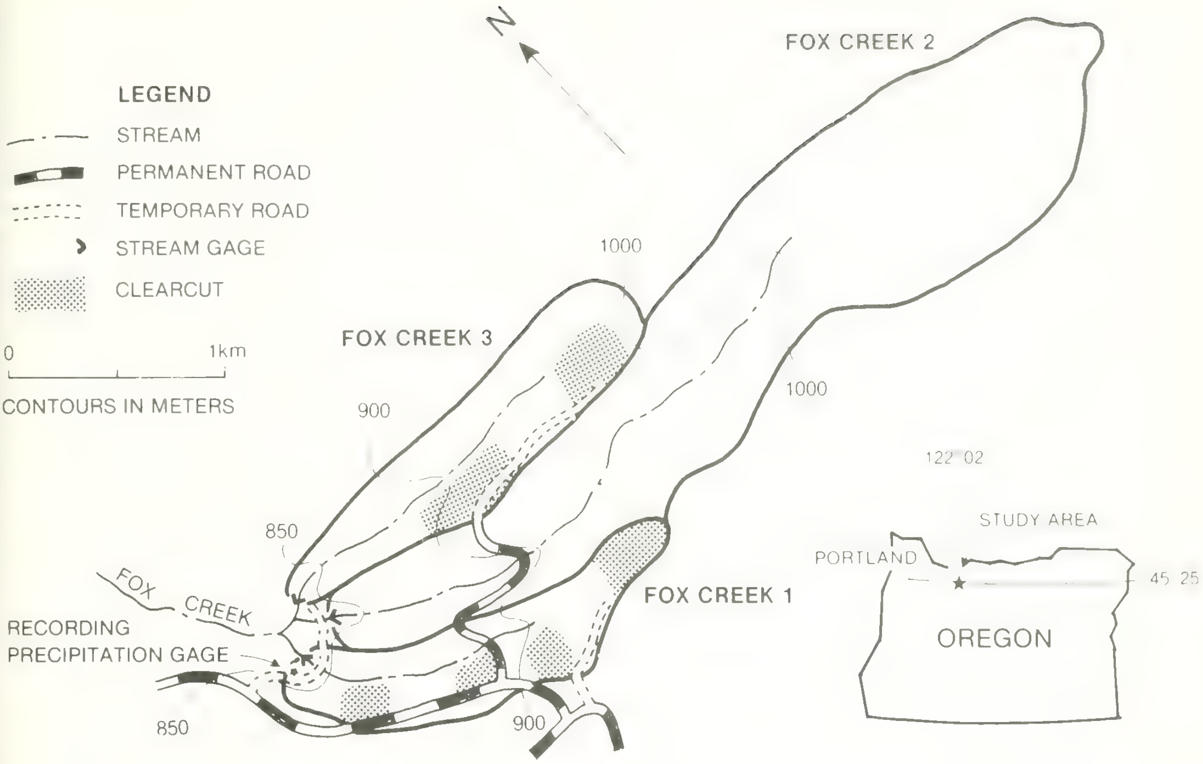

Figure 1.--The Fox Creek Experimental Watersheds.

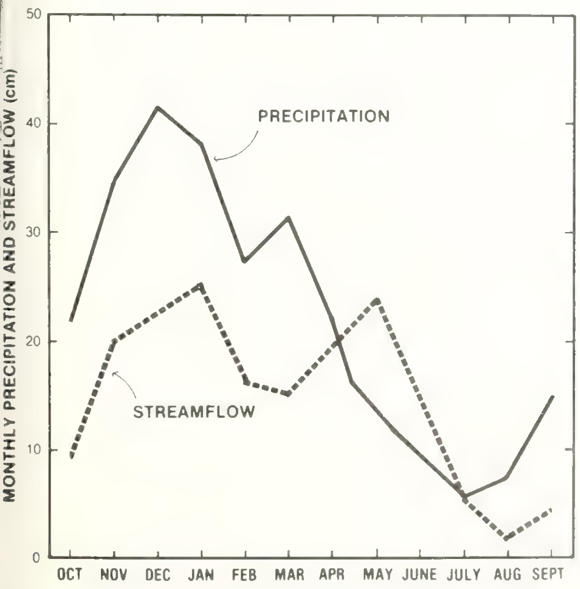

Figure 2.--Mean monthly precipitation at Fox Creek gage and streamflow at watershed FC-2, 1959-1977.

may begin accumulating in November and reach a maximum depth of more than 1.5 m by early April. During the summer, considerably more precipitation falls here than in most other areas of western Oregon. Also, fog or cloud interception by forest trees--and resultant drip--could be an additional, unmeasured source of precipitation. Fog drip has been described by field crews who have experienced "rainfall" (fog drip) under the forest canopy in all seasons, but found no water in the rain gage located in an open area nearby.

Streamflow, which has been measured continuously by trapezoidal flumes since the beginning of the 1957 water year (a water year runs from October 1 to September 30), has an annual pattern of distribution that reflects the general climatic pattern of the area (fig. 2). Typically, the major annual peak, which usually occurs in November, December, or January, results from rainfall or rapid snowmelt during rainfall. A second peak, which may be the maximum annual streamflow in any one year, often occurs during snowmelt in April or May. Minimum streamflow usually occurs between mid-August and mid-September.

Total annual water yield has varie considerably among the three watersheds. During 11 prelogging years, it averaged 235 cm at FC-3, 271 cm at FC-1 and, during 20 years of record, has averaged 175 cm at FC- the unlogged control watershed. These yields are 83, 94, 64 percen of average annual precipitation fo the same periods. This variation i runoff percentage is greater than would be expected for three simila watersheds located adjacent to one another and is much greater than corresponding variation observed i similar studies elsewhere in the western Cascades of Oregon (Rothach 1970, Harr et al. 1979). Part of th variation results from differences in annual precipitation caused by differences in elevation of the watersheds. Adjustment of annual precipitation by the isohyetal method yields average annual precipitation values of 279 cm, 294 cm and 284 cm for FC-1, FC-2, and FC- respectively. Another part of the variation may result from inaccurat determination of watershed boundaries, particularly along the upper ends of FC-1 and FC-2, where the ground surface is nearly level. Mor over, if fog drip is a significant source of precipitaton and is unequally distributed among the three watersheds, such unequal distribution also may account for some of the variation in average annual yields.

Harvest Activities

In August 1965, a 1-km all-weather road was completed across gentle topography in FC-1 and FC-2 to the south boundary of FC-3 (fig. 1). In addition, short temporary spur roads were built into the areas to be logged in FC-1 and in FC-3. In FC-1, timber was clearcut in four units of 3-4 ha in late spring of 1969, and high-lead yarding was completed in July. Logging residue in the four logged units was burned in the fall of 1970. Logging in FC-3 occurred over a 3-year period; cutting in two units of 8-10 ha began in the summer of 1970, and yarding was completed in August 1972. Both tractors and a high-lead cable system were used to yard logs. No residue was burned in FC-3. Logged area in each watershed constitutes 25 percent of the total watershed.

Data Analysis

In this type of study, relationships developed between logged and unlogged watersheds during a prelogging calibration period are far more important than absolute values of various streamflow characteristics. These relationships are the bases for evaluating changes in annual water yield, low flows, and instantaneous peak flows after logging. Annual water yield data were summed simply by water year, but summer low-flow data were summarized two ways. First, monthly water yields were summed by watershed for each consecutive month that monthly water yield at the unlogged FC-2 watershed was less than 5 cm, an arbitrary value. July, August, and September were the most common consecutive months of low flow, but the number of months did range from only one (July 1968 and August 1971) to five (June-October 1965 and July-November 1976). In a second analysis, the number of days of streamflow below a predetermined low-flow level was compared between the unlogged watershed and each of the patch logged watersheds. A low-flow day is defined as having a mean daily streamflow of less than 0.11 liters/s·ha (1 $ft^3/s \cdot mi^2$), again an arbitrary value. Annual water yield, low flow, and number of low-flow days at each logged watershed were then regressed on corresponding values of each variable at the control watershed.

Instantaneous peak flows greater than 5.6 liters/s·ha at FC-2, the control watershed, and corresponding peak flows at logged watersheds were tabulated by water year. (A frequency analysis shows that a peak flow of 5.6 liters/s·ha at FC-2 would occur, on the average, at least once a year.) Peak flow at each patch logged watershed was regressed on peak flow at the uncut watershed for both prelogging and postlogging periods. Because the major peak flows of December 1964 and January 1965 were estimated at FC-1, these two events were excluded from analysis of peak-flow data. There were 14 events in each of the prelogging and postlogging periods in the FC-1 analysis, and 18 prelogging and 12 postlogging events in the FC-3 analysis.

Linear regression was used to obtain prelogging and postlogging prediction equations for estimating annual water yields, low flows, and peak flows at FC-1 and FC-3 from values of these variables at FC-2. A difference between prelogging and postlogging data was hypothesized and tested by comparing two regression lines (Neter and Wasserman 1974, p. 160-167). For each streamflow variable, the hypothesis was that there was no difference between the two regressions; i.e., $\alpha_1 = \alpha_2$ and $\beta_1 = \beta_2$, where α is the intercept of the regression, β is the slope, and subscripts 1 and 2 denote prelogging and postlogging, respectively. If the computed *F* value used to compare mean squares was greater than the tabulated value, the hypothesis was rejected in favor of the alternate hypothesis that the prelogging and postlogging regressions are different.

Results and Discussion

Water Yield

Prelogging and postlogging regression equations for annual water yield are given in table 1 and are plotted in figures 3 and 4. I failed to reject the hypothesis tha prelogging and postlogging regressions are not different. There is a possibility that postlogging yields may have been decreased slightly (about 6 percent) at both watersheds, because postlogging regressions are below the prelogging regression lines. Such decreases, of course, are not statistically significant at the 0.05-level of probability. If, however, a probability level of 0.10 had been chose to test hypotheses, then prelogging and postlogging regressions at FC-1 would be significantly different.

Based on results of other water-yield studies in western Oregon, modest increases in yield had been expected in both patch logged watersheds. Because removing forest vegetation reduces annual evapotranspiration (interception losses and transpiration), more of the annual precipitation becomes available for streamflow. In a 101-ha watershed in the H. J. Andrews Experimental Forest east of Eugene, Oregon, wher three clearcut patches and clearing for roads totaled 30 percent of watershed area, increases in annual yield averaged about 17 cm 3 years after logging, compared to 46 cm on a 96-ha watershed that was completely clearcut (Rothacher 1970). In southwestern Oregon, water-yield increases averaged 9 cm the first 5 years after a 68-ha watershed was logged in 20 small clearcuts totaling 38 percent of watershed

Table 1--Prelogging and postlogging water yield relationships between logged watersheds (Y) and the control watershed (X)

Watershed and period	Equation	n	r^2	F
FC-1 prelogging	$Y = 0.53 + 1.55X$	8	0.84	[1]3.43
FC-1 postlogging	$Y = 14.81 + 1.39X$	9	.99	
FC-3 prelogging	$Y = -21.57 + 1.49X$	9	.91	[1]1.79
FC-3 postlogging	$Y = 12.93 + 1.26X$	8	.99	

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[1] Prelogging and postlogging regressions are not significantly different at the 0.05-level of probability.

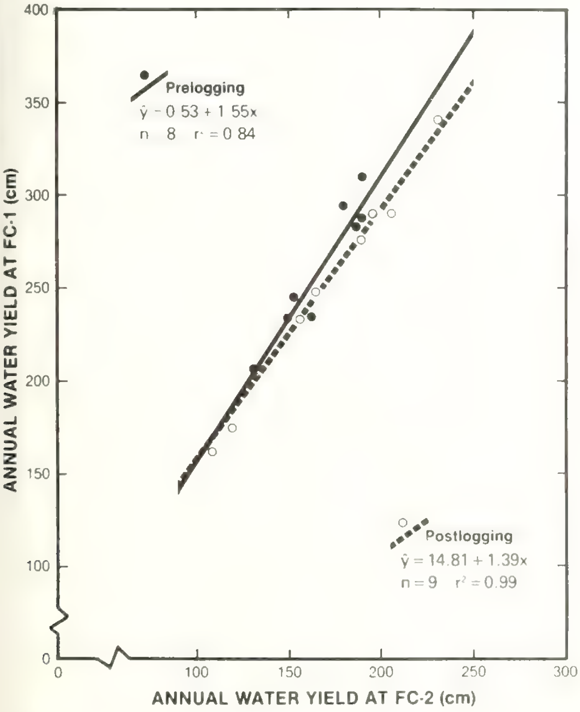


Figure 3.--Annual water-yield relationship between FC-1 and control watershed FC-2.

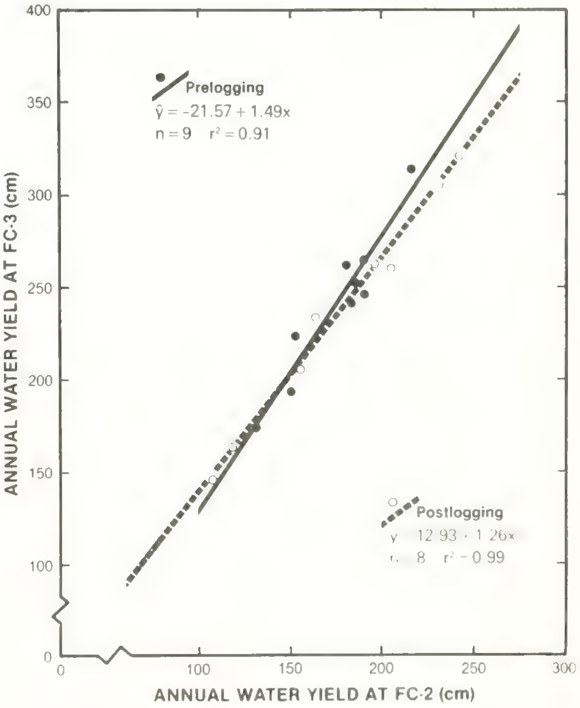


Figure 4.--Annual water-yield relationship between FC-3 and control watershed FC-2.

area (Harr et al. 1979), compared to a 30-cm average water-yield increase in an adjacent 50-ha watershed that was completely clearcut. Considering these measured increases and estimated annual losses to interception and transpiration at Fox Creek of at least 80 cm (U.S. Army Corps of Engineers 1956, p. 131-136, Luchin 1973), yield increases of about 10-15 cm had been expected.

Lack of expected increases in annual yield may have several possible causes. The first possibility was that FC-2 streamflow was changed by logging. If, because of obscure groundwater divides in some locations, the clearcuts in FC-3 and the upper clearcut in FC-1 (fig. 1) actually were located partially within the FC-2 groundwater basin, some of the effect of timber cutting on streamflow could have been included in streamflow measurement at the FC-2 stream gage. This would cause FC-2 annual yield to be greater than would otherwise be the case and could account for post-logging data points being below the prelogging regression lines in figures 3 and 4.

A change in FC-2 streamflow should be visible in a double-mass plot of streamflow and precipitation. As can be seen in figure 5, there is a distinct change in slope in the double-mass curve shortly after logging in FC-3. This slope change, however, is not conclusive evidence that FC-2 streamflow was changed after logging, for the slope change could also result from a change in precipitation measurement. Indeed, a double-mass plot of FC-2 precipitation versus precipitation at Bull Run Headworks, 9 km northwest of FC-2, shows an identical slope change (fig. 6). This supports a

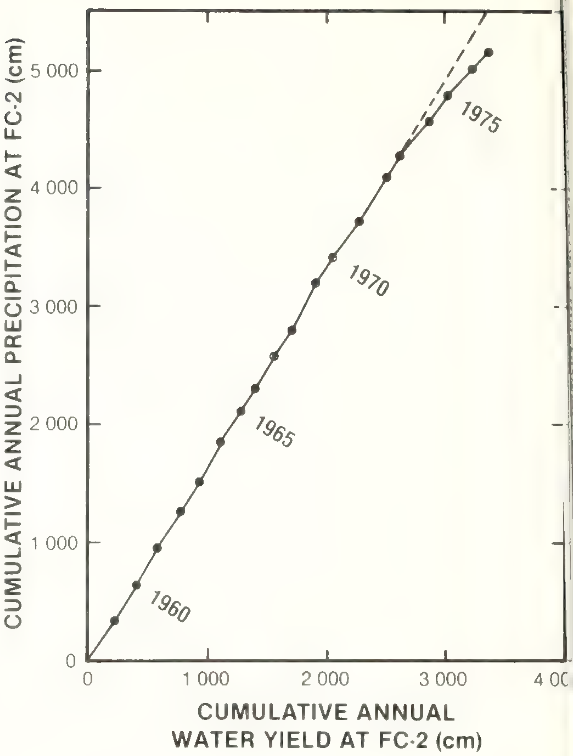


Figure 5.--Double-mass plot of cumulative annual precipitation and cumulative annual water yield at FC-

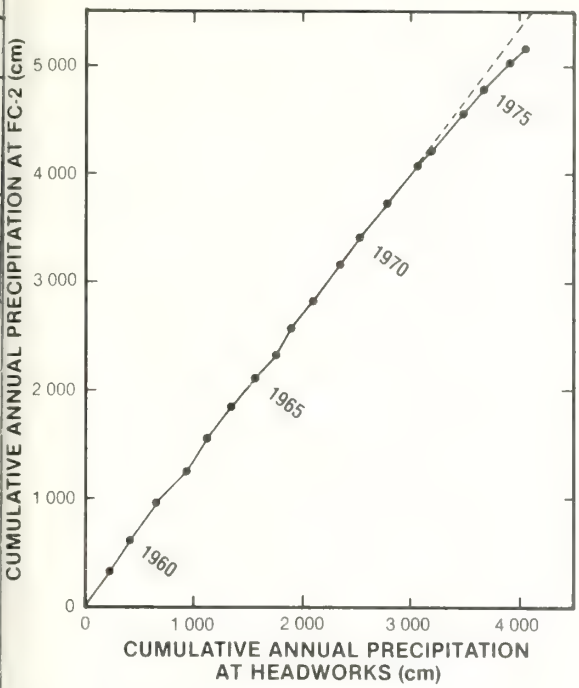


Figure 6.--Double-mass plot of cumulative annual precipitation at FC-2 and cumulative annual precipitation at Bull Run Headworks.

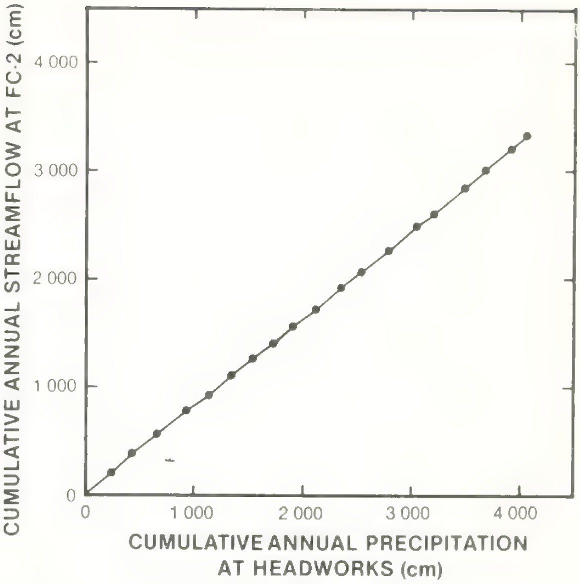


Figure 7.--Double-mass plot of cumulative annual streamflow at FC-2 and cumulative annual precipitation at Bull Run Headworks.

change in precipitation measurement at FC-2 as the explanation. Before February 1972, precipitation measurements at the recording rain-gage were not adjusted according to measurements with a standard storage gage, as is done currently. They could be about 2-4 percent higher than post-1972 measurements. Precipitation measurement rather than a change in FC-2 streamflow is the cause of the slope change in figure 5. That a double-mass plot of annual streamflow at FC-2 versus annual precipitation at Bull Run Headworks (fig. 7) shows no change in slope substantiates that annual streamflow at FC-2 has been unchanged by logging in FC-1 or FC-3.

The lack of expected increases in annual water yield also may involve fog or cloud interception by the forest canopy. If the forest stands that were cut had intercepted water droplets in clouds, and subsequent drip from these stands was an important (though unmeasured) part of net precipitation, then removing these stands might have reduced total annual gross precipitation sufficiently to offset reduced transpiration from clearcut areas. The amount of fog or cloud interception at Fox Creek and its distribution over the study watersheds are unknown, but fog drip could be as high as 25-30 cm, according to results of several studies of fog interception along the Pacific coast. In general, these studies have shown that amount of drip is directly related to the area of tree profile and to the degree of exposure of trees to windblown fog.

On the Oregon coast, annual precipitation under the forest canopy was 252 cm, 52 cm (26 percent) greater than in the open (Isaac 1946). During a 46-day summer period in coastal northern California, fog drip beneath 18-m-tall Douglas-fir trees ranged up to 42.5 cm (Azevedo and Morgan 1974). In Hawaii, Ekern (1964) measured 76 cm of annual fog drip under a 9-m-tall pine tree, a 20 percent increase. Other published fog drip measurements include 152.4 cm and 5.2 cm beneath an exposed tanoak (*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.)) tree and a sheltered redwood (*Sequoia sempervirens* (D.Don) Endl.) tree, respectively, during the summer (Oberlander 1956) and 5.7 cm per month beneath knobcone pine (*Pinus attenuata* Lemm.) in southern California (Vogl 1973).

Amounts of fog drip measured in most of these studies are probably much greater than fog drip at the Fox Creek site. Even so, fog drip of 25-30 cm beneath the forest canopy at Fox Creek may not be an unreasonable estimate. Fog drip seems to be the most plausible explanation, so far, for the lack of increase in water yield after logging. Measurement of actual f drip at Fox Creek and assessment its importance in annual precipitation are necessary before the effects of timber cutting on stre flow are completely understood fo these small watersheds. Results from a fog drip study now underwa will be reported as they become available.

Low Flows

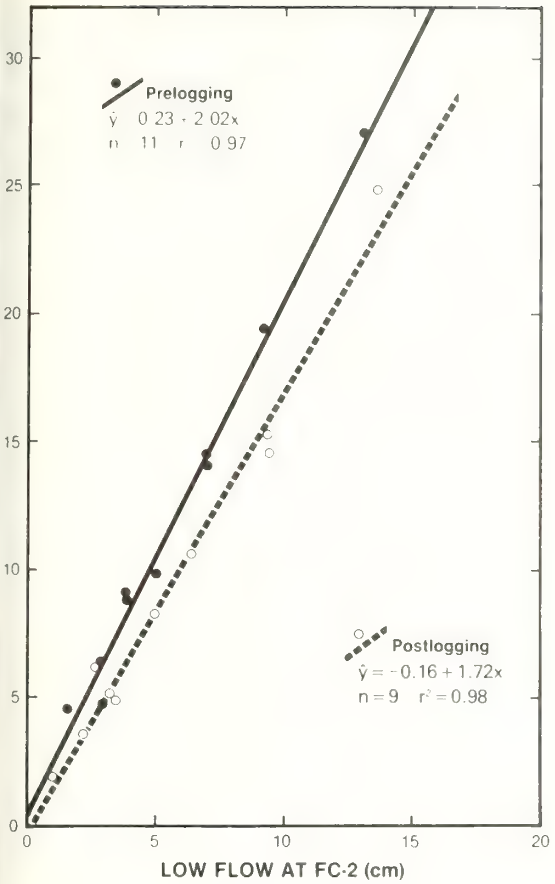
Prelogging and postlogging regression equations for low flow durin low-flow months are given in table 2, and relations for each period are plotted in figures 8 and 9. Prelogging and postlogging regressions are significantly different at FC-1, but not at FC-3 (table 2); streamflow at FC-1 was reduced, on the average, about 15-20 percent during the low-flow period.

Table 2--Prelogging and postlogging low-flow relationships between logged watersheds ($\hat{Y}$) and the control watershed (X)

Watershed and period	Equation	n	r^2	F
FC-1 prelogging	$\hat{Y} = 0.23 + 2.02X$	11	0.97	[1]9.63
FC-1 postlogging	$\hat{Y} = -.16 + 1.72X$	9	.98	
FC-3 prelogging	$\hat{Y} = .42 + 1.22X$	12	.82	[2].35
FC-3 postlogging	$\hat{Y} = .64 + 1.08X$	7	.87	

[1] Prelogging and postlogging regressions are different at the 0.05-level of probability.

[2] Prelogging and postlogging regressions are not significantly different at the 0.05-level of probability.



igure 8.--Relationship of low low between patch logged FC-1 and nlogged FC-2.

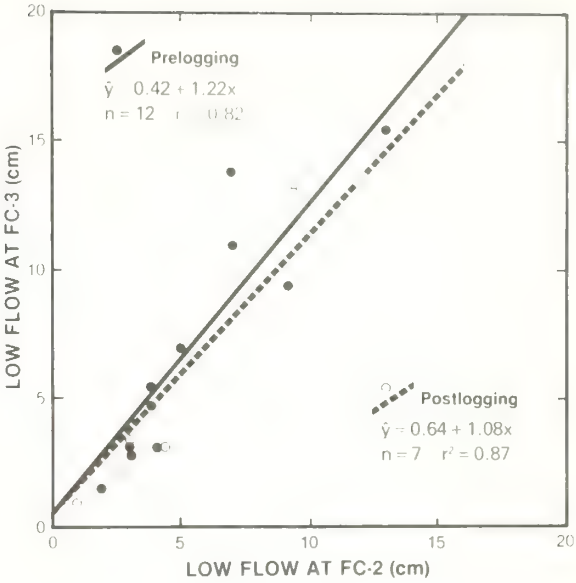


Figure 9.--Relationship of low flow between patch logged FC-3 and unlogged FC-2.

Prelogging and postlogging regression equations for number of low-flow days are given in table 3, and each period's relationships are plotted in figures 10 and 11. Prelogging and postlogging regressions are significantly different at both

Table 3--Prelogging and postlogging low-flow day relationships between logged watersheds (Y) and the control watershed (X)

Watershed and period	Equation	n	r^2	F
FC-1 prelogging	Y = -28.33 + 0.93X	11	0.83	[1]9.31
FC-1 postlogging	Y = 9.50 + .99X	9	.29	
FC-3 prelogging	Y = -25.78 + 1.26X	12	.90	[1]6.93
FC-3 postlogging	Y = 27.31 + .81X	8	.59	

[1] Prelogging and postlogging regressions are significantly different at the 0.05-level of probability.

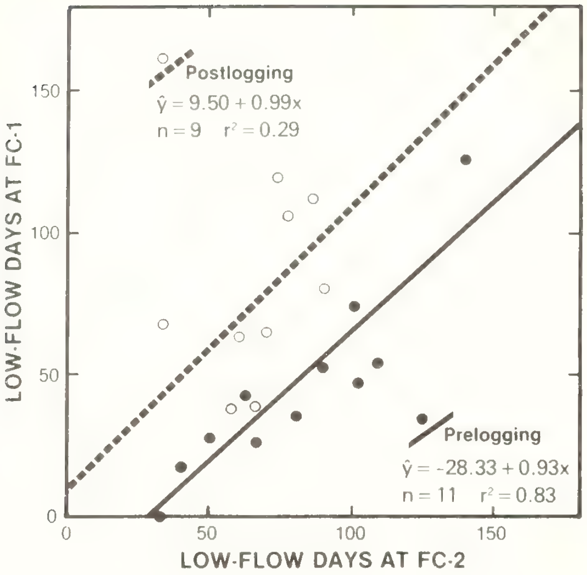


Figure 10.--Relationship of low-flow days between patch logged watershed FC-1 and unlogged FC-2.

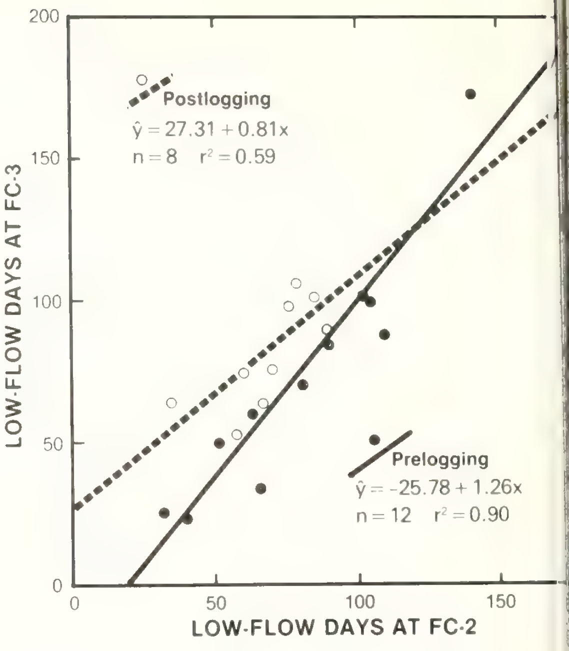


Figure 11.--Relationship of low-flow days between patch logged watershed FC-3 and unlogged FC-2.

FC-1 and FC-3; number of low-flow days increased relative to the number at FC-2--that is, streamflow during the low-flow period was reduced after clearcutting in patches.

Reduced summer flow as illustrated by both low-flow analyses at FC-1 and one analysis at FC-3 could also result from fog drip. If fog drip had added to total basin precipitation before logging, then removing timber stands that intercepted fog could have reduced effective precipitation and thus streamflow during summer low-flow periods.

Increased flows during summer low flow had been expected because timber cutting would make more water available for streamflow, particularly during the summer when forest vegetation is withdrawing water from the soil. Watershed studies elsewhere in Oregon have shown large relative increases in streamflow during the months of lowest flow. In the H. J. Andrews Experimental Forest, Rothacher (1971) found that average streamflow during the week of lowest flo tripled the year after a 96-ha watershed was clearcut and broadcas burned. Increases in summer flows were also noted at a nearby 101-ha watershed that was patch logged, but those increases were much smaller (Rothacher 1970). In the Oregon Coast Ranges, low flows were significantly increased all five postlogging years in a 70-ha watershed that had been 82-percent clearcut (Harr and Krygier 1972). At a second watershed which had been 25-percent clearcut in patches, increases in low flows were significant in only two of five postlogging years. In southwestern Oregon, streamflow during the July-September low-flow season was increased up to 400 percent the first 6 years after 100-percent learcutting one watershed, up to 00 percent after patch logging a econd watershed, and up to 80 ercent after shelterwood cutting a hird watershed (Harr et al. 1979).

eak Flows

elogging and postlogging regres- ion equations for peak flows are iven in table 4, and relationships or each period are plotted in igures 12 and 13. In general, peak ows at FC-1 and FC-3 were not ell correlated with corresponding eak flows at FC-2 during both elogging and postlogging periods evidenced by three r^2 values only 0.59 to 0.74. Prelogging d postlogging relationships are t significantly different at ither watershed. This was partly ecause of (1) natural variation in noff production between water- heds owing to differences in tershed size and elevation, (2) latively small numbers of peak- ow events suitable for analysis, d (3) probably only a very slight fect of logging on size of peak ows.

Significant increases in size of peak flows had not been expected because only 25 percent at FC-1 and FC-3 were logged, soil was disturbed on a very small part of the watersheds, and the gentle topography of the watersheds tends to reduce the likelihood of overland flow reaching a water course. Rothacher (1973) found increases in size of small peak flows only in the fall and spring after a steep 96-ha watershed was completely clearcut with little soil disturbance. Increases were attributed to wetter, hydrologically more responsive soils after logging because evapotranspiration had been reduced. After soils in the forested control watershed had been recharged, both forested and clearcut watersheds responded similarly, so that large peak flows in winter were nearly unchanged. Likewise, Harris (1973) found no significant increase in size of large peak flows in winter after clearcutting in a 71-ha watershed in the Oregon Coast Ranges. On the other hand, comparison of prelogging and postlogging peak flow relationships indicated size of winter peak flows at two other locations in

Table 4--Prelogging and postlogging peak-flow relationships between logged watersheds ($\hat{Y}$) and the control watershed (X)

tershed d period	Equation	n	r^2	F
C-1 prelogging	$\hat{Y} = -0.88 + 1.43X$	14	0.74	[1]1.26
C-1 postlogging	$\hat{Y} = -1.38 + 1.58X$	14	.59	
C-3 prelogging	$\hat{Y} = -.44 + 1.20X$	18	.91	[1].96
C-3 postlogging	$\hat{Y} = -2.01 + 1.60X$	12	.69	

[1] Prelogging and postlogging regressions are not significantly ifferent at the 0.05-level of probability.

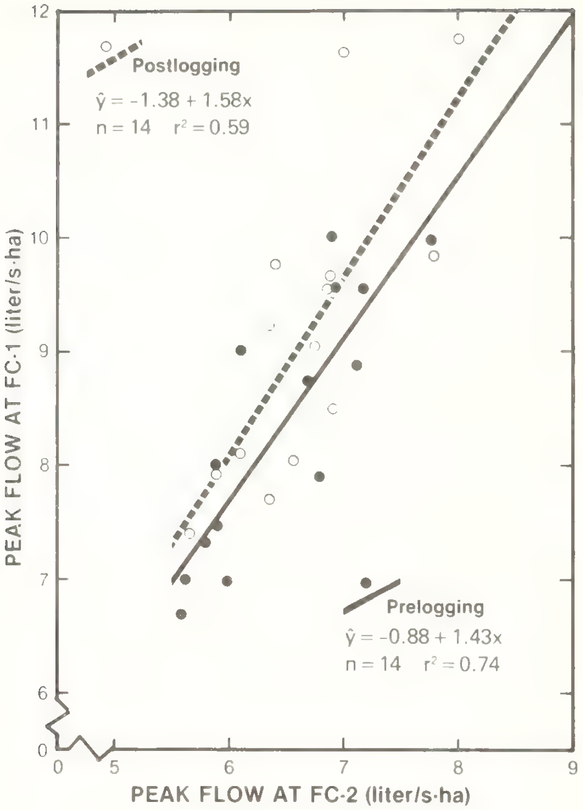


Figure 12.--Peak-flow relationships between patch logged FC-1 and unlogged FC-2.

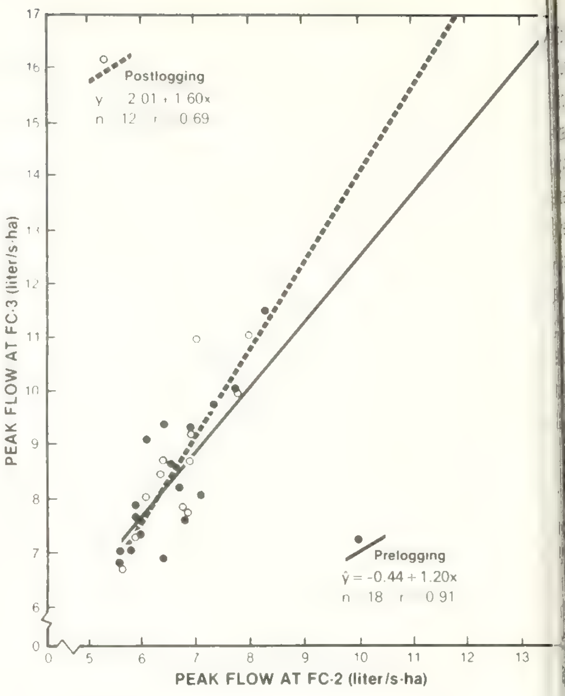


Figure 13.--Peak-flow relationships between patch logged FC-3 and unlogged FC-2.

western Oregon were significantly increased where compacted soils occupied at least 12 percent of total watershed area (Harr et al. 1975, Harr et al. 1979).

Where similar patch logging with minimal soil disturbance is done in other drainages in the 25-30 percent of the 270-km Bull Run Watershed that has slope gradients of <15 percent, size of instantaneous peak flows in winter most likely would not be changed. One exception may involve rapid snowmelt during rainfall. Comparing point estimates of snowmelt during rainfall for

orested and open areas (U.S. Army
orps of Engineers 1960) suggests
hat clearcutting on certain areas
ay increase the rate of snowmelt
y increasing the rate of air move-
ent and, thus, the amount of melt
esulting from convective heat
xchange and condensation of
ater vapor on the snow surface.
onvection-condensation melt is the
argest component of total melt
nder most rainfall conditions in
his region.

onclusions

nnual water yield and size of
nstantaneous peak flows were not
ignificantly changed, but low flow
ecreased significantly after two
xperimental watersheds were logged
n small clearcuts totaling
5 percent of watershed area.

cknowledgments

gratefully acknowledge the
ssistance of personnel from the
t. Hood National Forest, Columbia
orge Ranger District, and the City
f Portland Water Bureau. I am
ndebted to Al Levno and Ross
ersereau for data collection, to
hyllis Frazer for data processing,
nd to Dick Fredriksen for helpful
omments.

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English Equivalents

1 centimeter (cm) = 0.39 inches
1 meter (m) = 3.28 feet
1 kilometer (km) = 0.62 mile
1 hectare (ha) = 2.47 acres
1 liter per second per hectare (liter/s·ha) = 9.15 cubic feet per second per square mile

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Mailing address: Pacific Northwest Forest and Range
Experiment Station
809 N.E. 6th Ave.
Portland, Oregon 97232

Harr, R. Dennis.
1980. Streamflow after patch logging in small drainages within the Bull Run Municipal Watershed, Oregon. USDA For. Serv. Res. Pap. PNW-268, 16 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Annual water yields and size of peak flows were not changed, but low flows decreased significantly after patch logging in two small watersheds.

KEYWORDS: Streamflow -)forestry methods, logging (-hydrology, patch logging, Oregon (Bull Run Watershed)

GPO 990-575

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Research Paper PNW-269
May 1980

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Radial Growth in Grand Fir and Douglas-fir Related to Defoliation by the Douglas-fir Tussock Moth in the Blue Mountains Outbreak

B.E. Wickman, D.L. Henshaw, and S.K. Gollob

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Acknowledgments

[illegible] gratefully acknowledge A. G. Raske, [illegible] foundland Forest Research Centre for [illegible] ew and helpful suggestions. The [illegible] dy would not have been possible without [illegible] erest and protection of plots by [illegible] atilla and Wallowa-Whitman National [illegible]

[illegible] s research was funded [illegible]

Metric Conversions

[illegible] r = 0.4 inch
[illegible] 2.5 acres

Radial Growth in Grand Fir and Douglas-Fir Related to Defoliation by the Douglas-Fir Tussock Moth in the Blue Mountains Outbreak

Reference Abstract

Wickman, B. E., D. L. Henshaw, and
S. K. Gollob.
1980. Radial growth in grand fir and
Douglas-fir related to defoliation by the
Douglas-fir tussock moth in the Blue
Mountains outbreak. USDA For. Serv. Res.
Pap. PNW-269, 23 p. Pacific Northwest
Forest and Range Experiment Station,
Portland, Oregon.

Radial growth reduction related to amount of tree defoliation was studied following a severe tussock moth outbreak. Growth sharply declined the year after defoliation began, and amount of decline was proportional to percent defoliation. Growth recovery began the year after defoliation ceased and radial increment had returned to pre-outbreak levels 5 years after defoliation.

KEYWORDS: Increment (radial), defoliation damage, insect damage (-forest, Douglas-fir tussock moth, Orgyia pseudotsugata, grand fir, Abies grandis, Douglas-fir, Pseudotsuga menziesii, Oregon (Blue Mountains), Washington (Blue Mountains).

Research Summary
Research Paper PNW-269
1980

Radial growth of grand fir, Abies grandis (Dougl. ex D. Don) Lindl., and Douglas-fir, Pseudotsuga menziesii var. glauca (Beissn.) Franco, was measured following an outbreak of Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough), in the Blue Mountains of Oregon and Washington. All dominant and co-dominant trees were sampled from a series of plots established in 1972-73 to study the relationship of tree damage to tussock moth larval densities. Defoliation estimates made in 1972-73 were related to growth reduction of individual trees and stands. Adjustments were made to deduct losses due to environmental effects from gross growth reductions. We found that growth declined rapidly the year after defoliation began and reached its lowest point the 2d year after defoliation (1974). Radial growth recovery began in 1975 and had nearly returned to pre-outbreak levels by 1978. Environmental effects, especially from sub-normal precipitation, compounded the effects of defoliation during the outbreak and late recovery periods.

Percent defoliation was a good predict of growth reduction with losses proportional to severity of defoliation. A regression model comparing pre- and post-outbreak growth was developed for assigning expected growth declines to individual tree defoliation categories. Growth decline was most pronounced and similar for trees suffering 50-percent more defoliation.

Grand fir in this category suffered a n growth reduction of 57.9 percent and Douglas-fir a net growth reduction of 57.4 percent. Stand growth reductions were also proportional to stand defoliation severity. The pattern of growth decline and recovery for the four stand defoliation classes--heavy, moderate, light, and very light--conformed to tha of individual tree defoliation categori

Contents

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  Growth Related to Individual Tree Defoliation 4
  Growth Related to Stand Defoliation 4

LITERATURE CITED 19

APPENDIX 20

troduction

Douglas-fir tussock moth (DFTM),
yia pseudotsugata (McDunnough), is an
ortant defoliator of Douglas-fir,
udotsuga menziesii var. *glauca*
issn.) Franco, and true fir, *Abies*
., forests in western North America.
iodic outbreaks have caused severe
ber losses. Tree mortality accounts
most of the loss (Wickman 1978a), but
-kill and reduced radial growth may
significantly to the damage.

decline of white fir growth caused by
M defoliation is one of the most
stic on record for a forest defoliator
erber and Wickman 1970). The radial
wth configurations are so distinctive
t old outbreaks can be identified from
rement cores or discs from host trees
ckman 1963, Brubaker 1978).

vious studies of white fir defoliated
DFTM in California have shown severe
ial increment loss during and imme-
tely after defoliation (Wickman 1963).
growth reduction was also related to
ree of defoliation, with trees defo-
ted 75-90 percent suffering more than
ble the growth reduction of trees
oliated less than 25 percent. Growth
overy was usually not complete until 4
rs after defoliation. Growth measure-
ts had not been made of grand fir,
es grandis (Dougl. ex D. Don) Lindl.,
Douglas-fir after tussock moth defo-
tion so the pattern of radial increment
s and number of years of growth loss
unknown. It was suspected that grand
reacts similarly to white fir, but
response of Douglas-fir was
pletely unknown.

A recent extensive outbreak in the Blue Mountains of Oregon and Washington offered the opportunity to study tree damage resulting from defoliation by extremely dense populations of DFTM. The objective of studies begun in 1972 was t use defoliation intensity in 1972 and 1973 as a predictor of tree damage durin and after the outbreak. Two important forms of damage, tree mortality and top-kill, have already been summarized from this study (Wickman 1978a). The three forms of damage have also been mathematically represented in the DFTM outbreak model (Overton and Colbert 1978). This paper summarizes the effects of defoliation on radial growth during and immediately after the outbreak.

Methods

Location and Defoliation Classes

A series of 1/50th-acre damage plots was established in conjunction with six replicated tussock moth population study areas (Mason 1976) in the Blue Mountains to study the effects of defoliation (fig. 1). The area of study covered a 100-km transect of the tussock moth outbreak on the Umatilla and Wallowa-Whitman National Forests and included four additional heavily defoliated areas not included in the population study. The Forest Service mapped the outbreak from the air in 1972 (Graham et al. 1975) and stratified it into four defoliation classes; heavy, moderate, light, and very light. In addition, five individual tree defoliation classes as shown in figure 2 were used based on the percent of crown length totally defoliated (Wickman 1978a). Defoliation estimates of each plot tree were recorded as one of the seven classes immediately after the year of most intense defoliation (1972 or 1973).

Sampling Techniques

Clusters of 10-15 damage plots were systematically established at each of the 22 populations study points and at some additional heavily defoliated areas. Every tree over 1-in d.b.h. on the 1/50th-acre circular plots was tagged, measured, and its defoliation estimated. Complete information on plot establishment, tree measurements, and examinations is given in detail in Wickman's (1978a) publication.

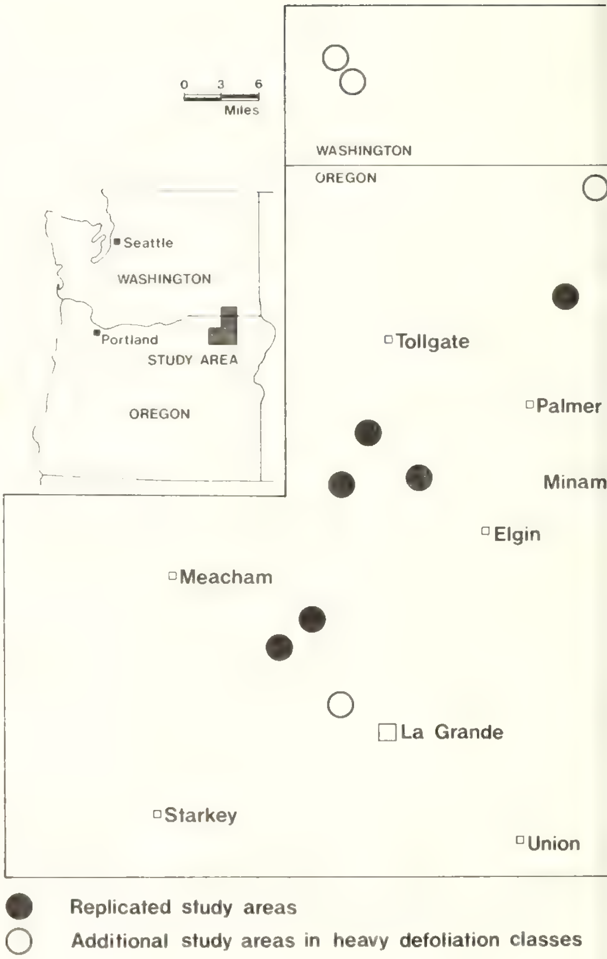
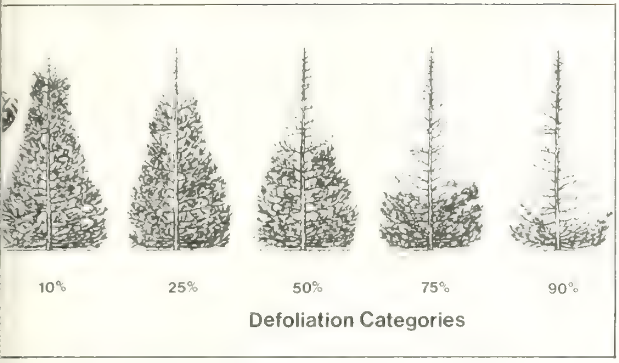


Figure 1.--Location of tree-damaged plot clusters in northeastern Oregon and southeastern Washington.



*ure 2.--Defoliation classes used in
imates, for individual trees, of
cent of crown totally defoliated,
2-73. Inset shows partial defoliation
lower branches.*

the end of the 1977 and 1978 growing
sons (late August through mid-
tember), increment cores were taken
n every dominant and co-dominant grand
and Douglas-fir on the plots. In
ition, one dominant or co-dominant non-
t tree (if present) was cored on each
t. Twenty-one mature ponderosa pine
e sampled from a pine stand on a dry
ge (sensitive site) in the outbreak
a to compare general tree growth pat-
ns to climate (Fritts 1976). Non-
oliated host trees were cored from
n of five check areas contiguous with
adjacent to the outbreak. Controls
e as close as 1 kilometer and never
ther than 8 kilometers from defoliated
nds. A breakdown of sample trees
lows:

	No. trees
iated host trees (grand fir and glas-fir) on plots	530
efoliated host trees off plots	70
ost trees on plots (pine, larch, spruce)	89
ost trees (pine) on sensitive site	21

Two increment cores were taken per tree at d.b.h., except trees defoliated 50 percent or more had four cores taken in 1978 to help account for partially missing rings. The cores came from two quadrants at 90 degrees, usually the north and west if possible, as suggested by Fritts (1976). Cores were taken to the pith to include the total age of the tree in 1977, and cores including only the last 12 years were taken in 1978.

A Bannister incremental measuring machine (fig. 3) was used to measure annual increment on the cores to the nearest 0.01 mm as described by Stokes and Smiley (1968). Measurements were automatically printed on tape and later punched on cards for computer analysis.

Figure 3.--A Bannister dendrochronograph used to measure annual growth on increment cores.

Analysis

Data were summarized and then graphed to show growth patterns of trees in individual tree defoliation classes, in each of the four aerially mapped defoliation classes, and in the four defoliation classes stratified by ground measurements. Diameter growth at d.b.h. is used as the principal growth parameter; however, basal area growth increment at d.b.h. was also examined. An example using this method is given for comparison on page 6.

A method was developed to estimate percent radial growth reduction for individual tree defoliation categories. Nondefoliated host sample trees are used to detect changes in growth patterns due to general environmental conditions from the pre-outbreak through the outbreak growth period. These patterns are assumed to hold true for defoliated host trees, and are used to obtain expected growth during the outbreak period. Then, actual growth of defoliated trees during the outbreak period is compared with the estimated expected outbreak growth to determine percent growth loss. An equation is derived to estimate this growth loss. Using this method, percent radial growth loss is determined based on diameter increments and on basal area increments.

A comparison of growth rates among individual tree defoliation categories using regression analysis and analysis of covariance was conducted. Regressions of post-outbreak growth on pre-outbreak growth are examined for each of these defoliation classes and tested for significance. An analysis of covariance was then used to test for differences among these linear relationships. When statistically examining the growth characteristics of individual trees, we are assuming independent random sampling of trees even though trees occur in groups by plot clusters.

Results and Discussion

Growth Related to Individual Tree Defoliation

Defoliated Tree Classes

The downward trend in growth of defoli trees began in 1972, but may have been due more to environmental factors than defoliation (fig. 4a-b). By 1973, there were sharp declines in growth for all defoliation categories; and in 1974, th year defoliation ceased, growth reached its lowest point. In 1975, growth start to increase and this continued until 1 when growth returned to normal levels f all but the most severely defoliated trees. Depression of growth was directl proportional to defoliation with the mo severely defoliated trees (both grand f and Douglas-fir) exhibiting the greates growth loss. The same relations are app tioned by 5-year periodic annual increments (fig. 5a-c). This is easier to de pher because four, 5-year periods of growth--three before the outbreak, and each during and immediately after--smoo annual variation and for Douglas-fir particularly help define relationships.

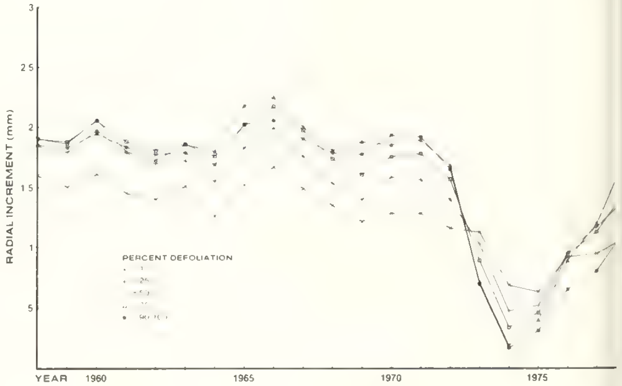
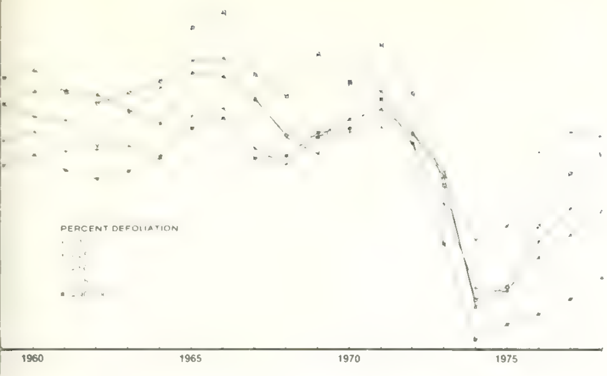
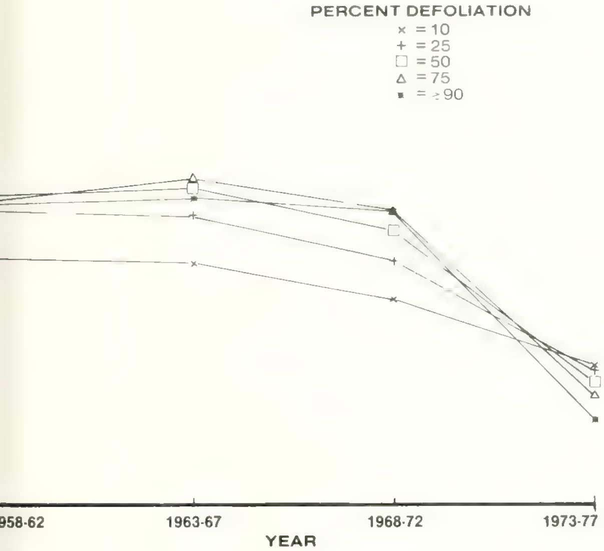


Figure 4a.--Grand fir average radial gr of individual tree defoliation classes.



re 4b.--Douglas-fir average radial th of individual tree defoliation ses.



re 5a.--Grand fir average radial growth ndividual tree classes in 5-year odic annual increments.

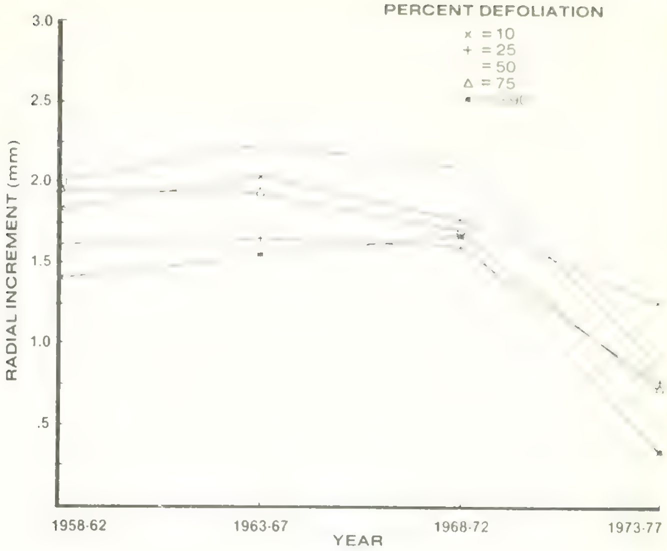


Figure 5b.--Douglas-fir average annual growth of individual tree classes in 5-year periodic annual increments.

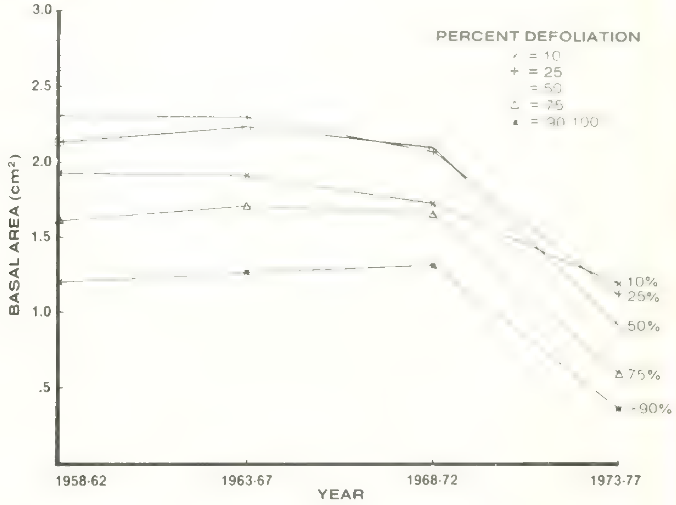


Figure 5c.--Grand fir average basal area growth of individual tree classes in 5-year periodic annual increments.

Grand fir suffering the lightest amount of defoliation (10 percent or less) had the poorest pre-outbreak growth rate, while some of the most severely defoliated trees had the highest growth rates (fig. 4a, 5a). This unusual pattern could either be real or an anomaly. When annual basal area growth is measured in square centimeters at d.b.h., this relation is reversed when graphed (fig. 5c).[1] Basal area measurements tend to reduce annual variations and compensate for declining rate of growth after a tree reaches maturity. Basal area percent growth reductions, however, were similar to our diameter percent growth reduction measurements.

A comparison of 5-year pre-outbreak with 5-year post-outbreak growth was made using regression analysis to test whether a linear relationship exists between pre- and post-outbreak growth. These linear relationships were found to be highly significant for every grand fir defoliation category and all but the 10- and 90- to 100-percent classes for Douglas-fir. Non-significance for these two categories was probably due to very small sample size. Each tree defoliation category indicated that post-outbreak growth was significantly less than pre-outbreak growth (fig. 1a-b, appendix). Post-outbreak growth for non-defoliated host (fig. 2a-b, appendix) was significantly correlated with and similar to pre-outbreak growth rates. When the linear relationships between individual tree categories are compared (fig. 6a-b), grand fir particularly shows a consistent pattern of growth declining more rapidly as defoliation increases.

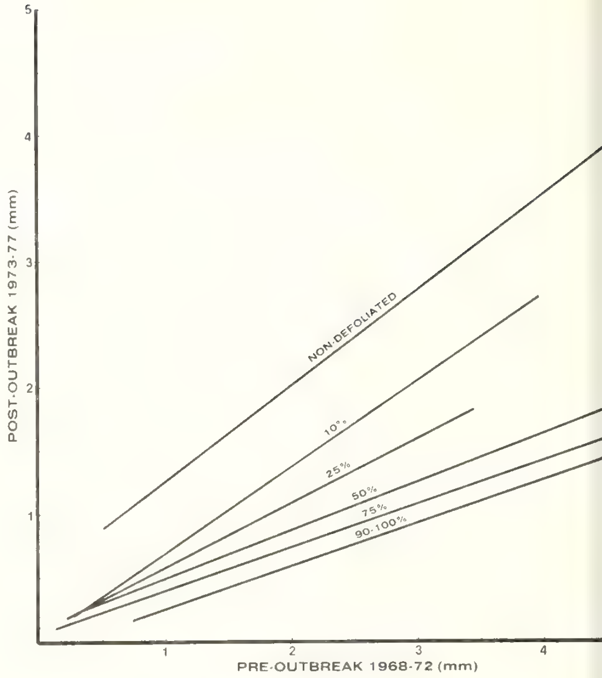


Figure 6a.--Radial growth of grand fi by percent defoliation.

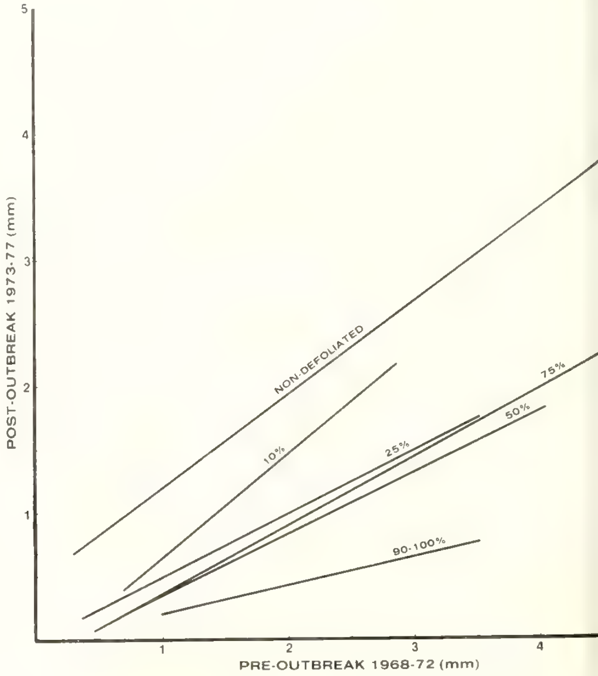


Figure 6b.--Radial growth of Douglas- by percent defoliation.

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[1] This analysis was suggested and a computer program developed to convert diameter growth to basal area in square centimeters of growth by Dr. Scott Overton, Oregon State University.

nalysis of covariance was used to test differences among individual tree liation categories where pre-outbreak th was the covariate and post-outbreak th was the dependent variable com- d. When testing for differences among six defoliation categories (including defoliated) for grand fir, a signifi- difference in slope was detected. a comparison of all grand fir classes ≥50-percent defoliation was made, no difference in slope was detected .34, d.f.=2,258). A test of adjusted s, however, was highly significant 1.89, d.f.=2,260) indicating greater th loss with greater amounts of defo- ion (fig. 6a, and appendix 1a and 2a). the 10- and 25-percent defoliation ses were compared, a difference in e was detected signifying differing -outbreak growth patterns for these classes.

analysis of covariance for Douglas- defoliation classes showed no dif- nce in either slope or adjusted means the 25-, 50-, and 75-percent classes. of significant differences among sted means seems most likely due to verall small sample for Douglas-fir. ter growth loss, however, is again rally correlated with increasing defo- ion (fig. 6b, and appendix 1b and 2b).

e analyses also indicate that growth erns for three classes of each tree ies (50, 75, 90-100 percent for grand 25, 50, 75 percent for Douglas-fir) similarly affected by defoliation. ther words, when defoliation intensity hes 50 percent for grand fir, then post-outbreak growth decline pattern ssentially established and remains lar for that category and any higher liation categories. For Douglas-fir, critical defoliation level appears to 5 percent; but small sample size s this a less reliable inference.

Sample size for Douglas-fir was not equivalent to that for grand fir because Douglas-fir comprised only 20 percent of the stand on the plots. The sample size for this analysis follows:

	Individual Tree Defoliation Categories				
	10	25	50	75	90-100
	(Percent defoliated)				
Grand fir	47	158	170	64	30
Douglas-fir	4	14	23	11	7

The pre- and post-outbreak growth regression model can be useful for assigning expected growth declines to individual tree defoliation categories, stratified by trees growing at different pre-outbreak rates, for stands in the Blue Mountains.

Growth decline at d.b.h. exhibited a 1-year lag from year of defoliation. In 1972, there was little growth decline even in heavily defoliated trees indicating trees were able to continue near normal growth using stored food reserves (Kulman 1971). The lowest point of growth occurred in 1974, the year after the last defoliation. From 1975 through 1978, the growth at d.b.h. consistently increased. Higher than average precipitation in 1975 helped growth recovery. Conversely, 1976 a subnormal year and 1977 a record drought year adversely affected growth in nondefoliated trees. Precipitation records for the Blue Mountains showed about a 2.5-in departure from normal for 1976 and 1977, yet the growth trend was consistently upward for defoliated trees in contrast to the downward trend for nondefoliated samples. Reduction of intertree competition for sunlight and moisture resulting from defoliation and tree mortality (Wickman 1978b) and increased nutrient cycling (Klock and Wickman 1978) probably encouraged growth recovery by the 5th year after the outbreak.

Percent Growth Reduction

The amount of growth reduction caused by defoliation is an extremely difficult value to estimate because of the problems of precisely identifying and quantifying the effects of extrinsic effects other than defoliation. In the previous section we examined some possible growth trends related to precipitation. Other effects due to competition for moisture, sunlight, and nutrients are almost impossible to estimate.

An estimate of percent growth reduction for the individual tree defoliation categories was determined by using average annual radial growth for a 15-year pre-outbreak period (1958-72) and a 5-year outbreak and growth loss period (1973-77) for defoliated and non-defoliated host trees. The non-defoliated host trees are used to account for growth changes due to environmental conditions and are used as an adjustment factor to estimate expected post-outbreak growth of defoliated host trees. A ratio of actual post-outbreak growth to expected post-outbreak growth of defoliated host trees is used to estimate percent growth reduction. Graphically, this method is easily understood, and a simple formula is derived.

Assume the growth behavior of non-defoliated host trees is similar to that of defoliated host trees from the pre-outbreak to post-outbreak periods.

A = Mean annual growth of defoliated trees during the post-outbreak period.
B = Mean annual growth of defoliated trees during pre-outbreak period.
C = Mean annual growth of non-defolia trees during the post-outbreak period.
D = Mean annual growth of non-defolia trees during the pre-outbreak period.
E = The expected mean annual growth o defoliated trees during the post- outbreak period (i.e., assuming there was no defoliation).
R = An estimate of the ratio of actua outbreak growth to expected growt

Assume:

$$\frac{B}{D} = \frac{E}{C}, \text{ then } E = \frac{BC}{D},\ R = \frac{A}{E},\ R_1 = \frac{A}{B},$$

$$R_2 = \frac{C}{D}, \text{ and } R = \frac{A}{E} = \frac{AD}{BC} = \frac{A/B}{C/D} = \frac{R_1}{R_2} .$$

Thus, R, an estimate of the ratio of actual outbreak growth to expected grow is easily determined. Then, 1-R becomes measure of growth reduction, and (1-R) x 100 is an estimate of percent net gro reduction.

The symbol R_2 is a sample adjustment factor, adjusting R_1 for various environmental effects on growth pattern In this analysis R_2 is calculated for both host species, Douglas-fir and grand fir.

This growth loss model was applied to b diameter increment growth (millimeter) basal area increment growth (square centimeters). The following values of R serve as sample adjustment factors for determining percent radial growth loss percent defoliation categories.

	Sample Adjustment Factors (R_2)	
	Diameter increment	Basal area increment
d fir	0.904	1.031
las-fir	.893	.979

relationship is shown graphically for nd fir and Douglas-fir trees defoliated percent or more in figure 7a-b. Both cies suffered almost identical percent growth reduction due to defoliation, 9 percent for grand fir and 57.4 per- t for Douglas-fir. The growth loss due environmental factors was 9.6 percent grand fir and 10.7 percent for glas-fir.

cent growth loss for each tree defo- tion category is listed in table 1.

le 1.--Percent net growth reduction, 3-77, by individual tree defoliation egories

ecies	Defoliation	Diameter increment in mm linear growth	Basal area increment in cm^2 area growth
		Percent	
fir	10	32.7	37.8
	25	45.7	50.6
	50	55.0	58.9
	75	60.7	65.5
	≥90	68.6	72.2
as-fir	10	23.9	27.2
	25	45.8	47.5
	50	54.1	58.4
	75	55.8	55.6
	≥90	75.3	70.8

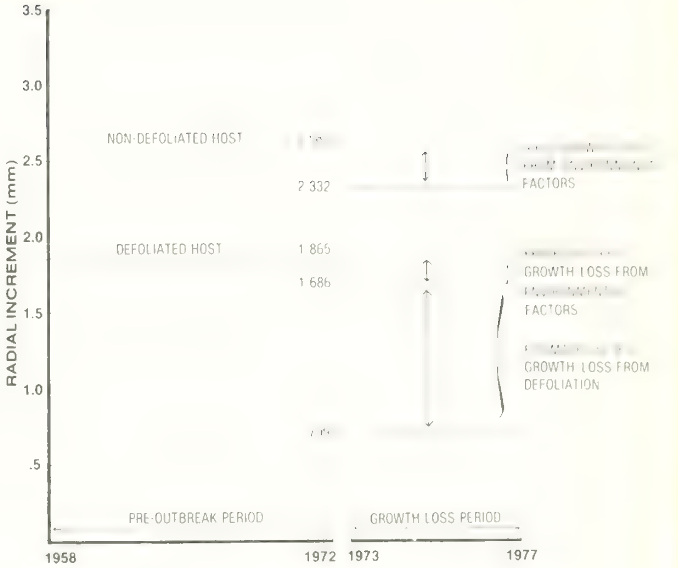


Figure 7a.--Estimated radial growth loss of ≥*50-percent defoliated grand fir from tussock moth defoliation based on average radial growth for pre-outbreak and outbrea periods.*

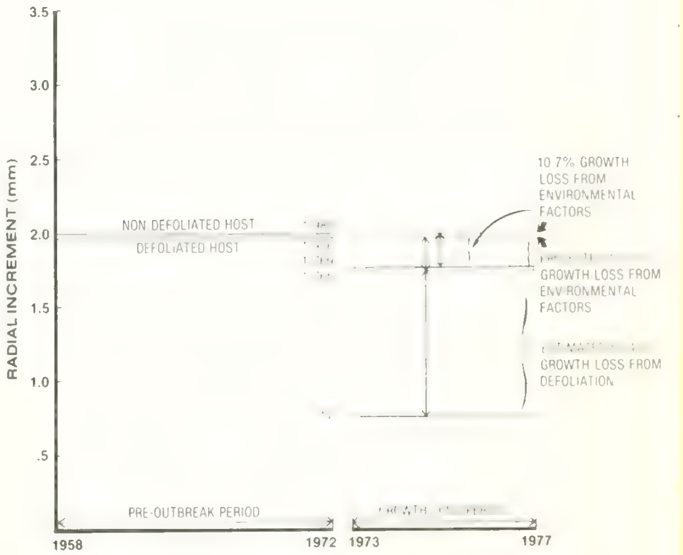


Figure 7b.--Estimated radial growth loss of ≥*50-percent defoliated Douglas-fir from tussock moth defoliation based on average radial growth for pre-outbreak and outbrea periods.*

Estimates of percent growth reduction are somewhat imprecise because of the complicating factors mentioned earlier. They are an important indication, however, of short-term tree damage, that is useful to forest managers. The only previous measurement of percent growth reduction following DFTM defoliation was made after a California outbreak (Wickman 1963). In that case, the reduction during the year following defoliation was calculated as a percentage of the average annual growth during the four years immediately preceding defoliation. Non-defoliated trees also declined slightly during the infestation period, but no record was made of the amount. Most studies of growth decline suffer from this inability to account for environmental effects and to deduct those effects from the gross amount lost after defoliation. In the California study, heavily defoliated trees (50-percent or greater defoliation) suffered 74-percent unadjusted (R_1) growth loss during a 4-year post-outbreak period. In this study, grand fir ≥50-percent defoliated suffered an unadjusted growth loss of 62 percent during a 5-year post-outbreak period. This is similar to the California outbreak except recovery was a year later in the Blue Mountains and this may have been influenced by the 1977 drought.

The short-term growth reductions found after defoliation by the DFTM in the Blue Mountains are strikingly similar to those found after other outbreaks (Wickman 1963, 1978b, Brubaker 1978). The effects on growth are immediate and pronounced for most degrees of defoliation, and recovery seems to take place shortly after defoliation ceases.

Diameter Classes

All defoliated trees were separated int five diameter classes and compared. Gro trends were similar for most diameter classes except for grand fir 1-6 inche in diameter which suffered the lowest growth rate in 1974 and 1975 (fig. 8a- For both species, small poles (13- to 18-in diameter) had the fastest growth rates before and recovery after defoliation, while the largest trees (>24- diameter) had the slowest recovery rate

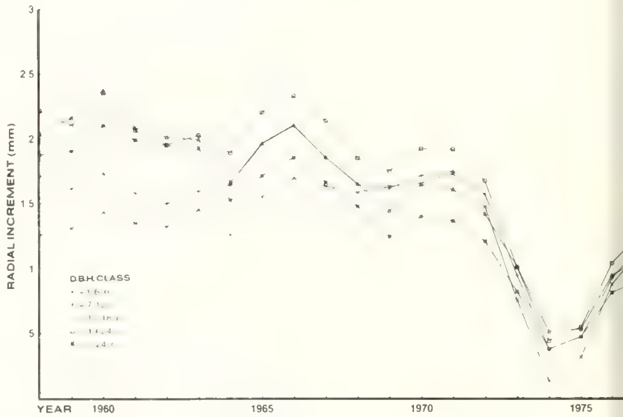


Figure 8a.--Average radial growth of grand fir by d.b.h. class.

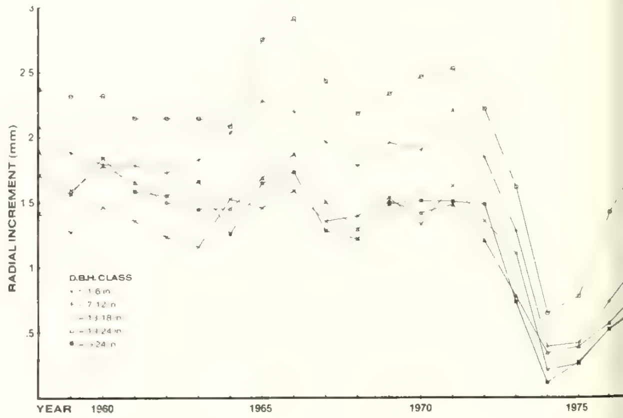


Figure 8b.--Average radial growth of Douglas-fir by d.b.h. class.

number of sample trees for each of d.b.h. classes is given below:

	D.b.h Class				
	1-6	7-12	13-18	19-24	>24
	(Inches)				
nd fir	31	206	86	62	84
glas-fir	5	21	15	8	10

distribution of d.b.h. by 1-inch ervals for all defoliated and non-oliated host trees is presented in the endix (table 2). The sample is biased ard the larger trees in the stands ce we sampled only dominant and co-inant trees which tend to be largest.

-Kill Classes

-kill is a common result of tussock h outbreaks, and in the Blue Mountains percent of the grand fir and 16.4 per-t of the Douglas-fir suffered top-kill. percent of each species suffered top-l amounting to 25 percent or more of crown (Wickman 1978a). A tabulation made of top-killed trees in our sample analyze the effects of top damage on ial growth. Our sample size for classes top-kill follows:

	Top-Kill Class		
	None or leader only	1-25%	>25%
nd fir	332	70	21

	None or leader only	Top-killed
glas-fir	39	8

Grand fir with 25 percent or less top-kill exhibited the same relative growth decline and slightly better recovery than trees with no top-kill. Trees with top-kill exceeding 25 percent showed less than half the growth recovery by 1978 as trees with no top-kill (fig. 9a). The top-killed grand fir were also growing at a faster rate prior to the outbreak than the trees without top-kill. Since most top-kill occurred in trees defoliated 75 percent or more, this indicates that perhaps the most vigorous trees (fastest growing) were supporting the highest tussock moth populations.

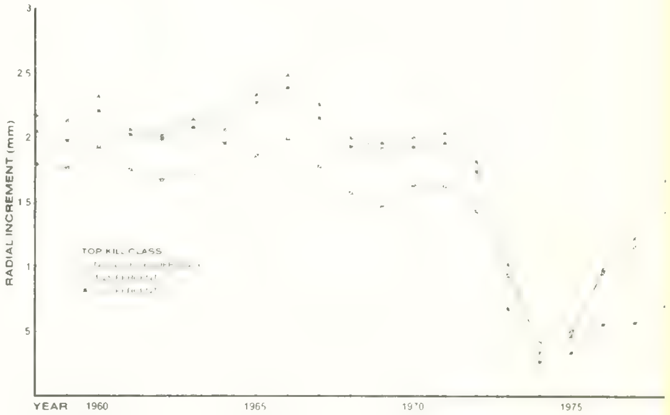


Figure 9a.--Average radial growth of grand fir by top-kill class.

The sample size for Douglas-fir was so small that all top-killed trees were included in one class. The eight top-killed Douglas-fir showed a similar growth decline and slower recovery than trees with no top-kill (fig. 9b).

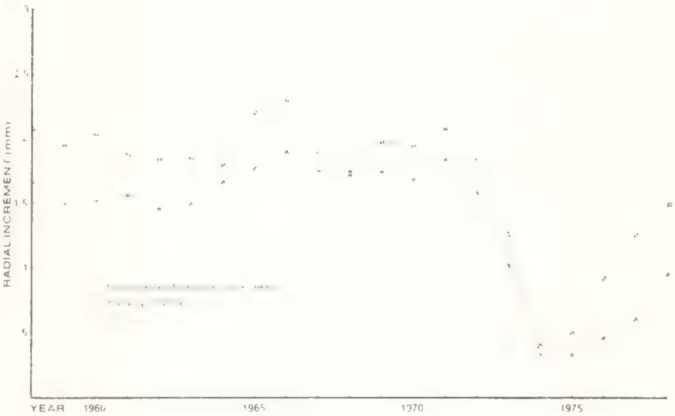


Figure 9b.--Average radial growth of Douglas-fir by top-kill class.

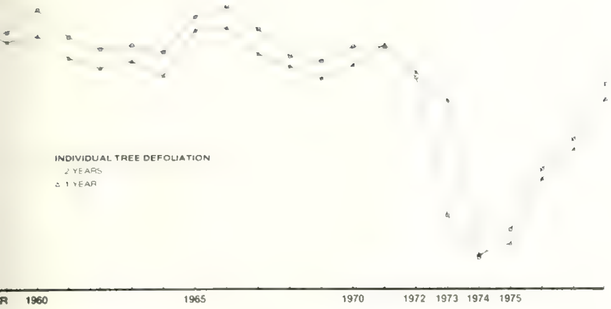
Comparison of 1 Versus 2 Years of Defoliation

The effects of 1 year of severe defoliation versus 2 years on growth of grand fir and Douglas-fir were determined for trees defoliated 50 percent or more. The sample size was as follows:

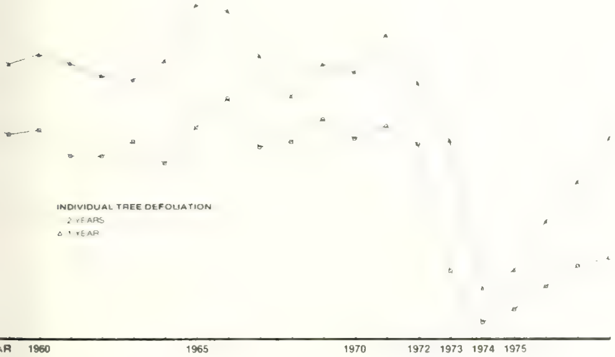
	Defoliated ≥50 percent	
	1973 only	1972 and 1973
Grand fir	45	128
Douglas-fir	24	11

The growth patterns for both classes o grand fir are similar until 1973. At t time, the trees defoliated 50 percent more in 1972 and again in 1973 exhibit a sharp decline while those defoliated percent or greater only in 1973 did no sharply decline until 1974 (fig. 10a). After 1974, recovery was almost identi for the trees defoliated only 1 year a those defoliated 2 years.

Douglas-fir trees in the two classes h a different growth pattern than grand (fig. 10b). Trees defoliated 50 percen or more in 1972 and then defoliated ag in 1973 were slower growing prior to t outbreak and exhibited slower recovery This might indicate that Douglas-fir growth was more seriously affected by 2 years of defoliation than grand fir since they also suffered proportionall more top-kill and mortality in the outbreak (Wickman 1978a). This sample siz (11 trees) is small, however; and othe Douglas-fir growth patterns are simila to grand fir. For instance, we did not find that grand fir suffered a greater and differential rate of growth loss a reported by Williams (1966, 1967) afte defoliation by western spruce budworm the Blue Mountains. Our results agree with Brubaker and Greene (1979) who failed to find differences in growth o the two species in Idaho after tussock moth defoliation.



re 10a.--Average radial growth of
d fir defoliated in 1972-73 and
liated in 1973 only.



re 10b.--Average radial growth of
las-fir defoliated in 1972-73 and
liated in 1973 only.

Comparison of All Defoliated Versus Non-Defoliated Trees

Growth fluctuations caused by extrinsic factors are difficult to identify because there are usually several factors affecting tree growth in the same year. The effects of defoliation are usually so severe they conceal the effects from other causes such as precipitation. Therefore, a sample of trees which were not defoliated provides some indication of growth anomalies occurring during the outbreak and post-outbreak years without the obscuring effects of defoliation. To determine normal growth patterns during the outbreak and post-outbreak period, non-host trees, ponderosa pine, western larch, and Engelmann spruce, occurring on the defoliated plots were sampled. Even these trees, however, suffered defoliation in the severely defoliated stands. Therefore, five areas adjacent to the outbreak containing non-defoliated host trees, were also sampled. A tabulation of non-host trees sampled on the plots showed there were 56 pine, 12 larch, and 21 spruce. The total defoliated and non-defoliated host trees is given below:

	Defoliated	Non-defoliated
Grand fir	470	32
Douglas-fir	60	38

The non-host trees on the plots exhibited growth declines during the immediate post-outbreak period, 1973 and 1974, which may have been due in part to defoliation (fig. 11). All three species showed growth increases in 1976, the year after a good precipitation year, then a decline in 1977, a subnormal precipitation year, with larch and spruce continuing their decline into 1978.

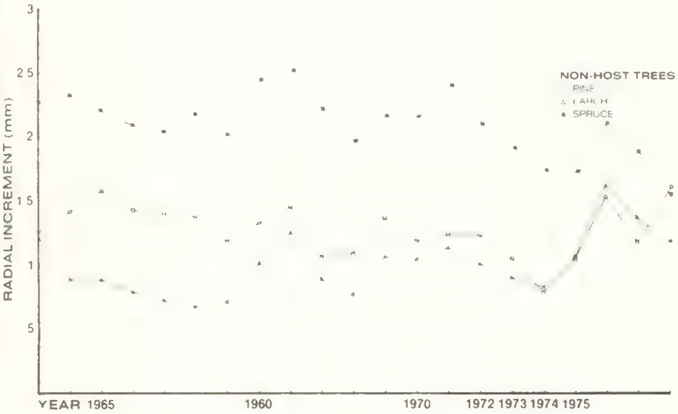
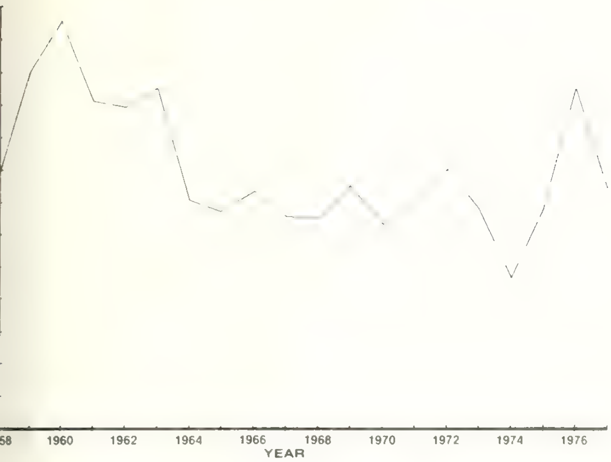


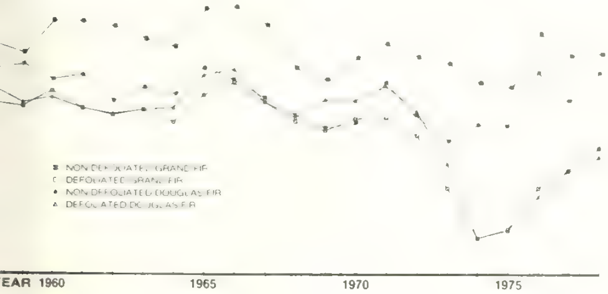
Figure 11.--Average radial growth of non-host trees.

There are other problems with using da from these non-host plot trees beyond 1974. Non-host trees on the plots are showing some growth effects from other extrinsic factors, namely reduced tree competition for sunlight, moisture, an nutrients caused by intermingled host mortality in the severely defoliated stands. There are also increased nutri from leaf litter fall and insect frass a result of defoliation (Klock and Wic 1978). These trees may be of more inte in long-term measurements of effects; for this study, their value is limited exhibiting pre-outbreak growth pattern

The sample of 21 pines from a pure pin stand on a dry ridge surrounded by def liated stands provides additional insi into the effects of environment on gro Because these trees are located on a d site, they are more sensitive to soil moisture changes regulated by precipit tion and reflect these changes readily their growth patterns (Fritts 1976). T year of greatest depressed growth of t pine, 1974, also coincides with the ye of greatest growth reduction of defoliated fir (fig. 12). This indicates t unfavorable environment compounded the effects of defoliation. In 1976, the p exhibited greatly increased growth as defoliated and non-defoliated fir (fig 13). Therefore, environment also playe positive role in the recovery of defoliated trees for at least 2 years afte the outbreak.



ure 12.--Annual diameter growth of
derosa pine from a dry ridge
rounded by defoliated stands.



ure 13.--Average radial growth of all
foliated and non-defoliated grand fir
Douglas-fir trees.

The growth configurations of non-defoliated host trees adjacent to the defoliated areas illustrates the typical expected growth during the post-outbreak years (fig. 13). There is, however, a complicating factor inherent in this sample. The non-defoliated grand fir has a much faster growth rate than the defoliated grand fir because the only place non-defoliated stands contiguous to the outbreak could be found were canyon bottoms. These sites had deeper soil, cooler temperatures, and more soil moisture than the outbreak areas. Consequently, the non-defoliated grand fir were fundamentally more vigorous trees than the defoliated grand fir. They did show downward growth trends in 1972, 1973, 1974, and 1977, however; this is probably related to lower precipitation during those years.

The non-defoliated Douglas-fir came from drier sites, and the growth pattern is similar to both defoliated grand fir and Douglas-fir through 1972. In 1973, 1974, 1975, and 1977, non-defoliated Douglas-fir had lower than normal growth; and this, too, was most likely associated with subnormal precipitation during the same years (fig. 14). It is also interesting to note that every class of non-defoliated tree had a growth decline in 1977, a record drought year for the Pacific Northwest; but every defoliated tree class exhibited some growth recovery that same year. This seems unusual for trees which had suffered such recent physiological shock and slow recovery and may lend additional credence to observations that decreased competition and increased nutrient cycling enhances tree recovery after outbreaks (Wickman 1978b).

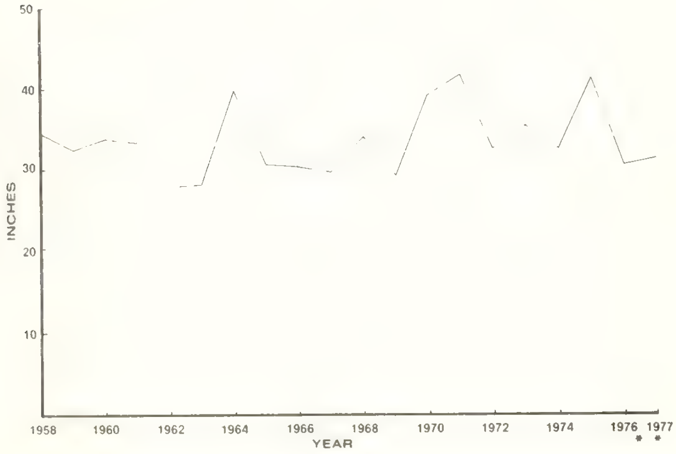


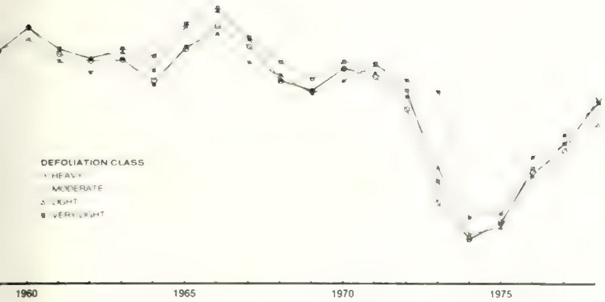
Figure 14.--Annual precipitation at Meacham, Oregon. (Adjusted from Gibbon, Oregon, annual precipitation.)*

Growth Related to Stand Defoliation

The growth study was designed primaril to examine the effects of defoliation individual trees. Amount of defoliatio was chosen as the variable most useful for predicting tree damage. The arrang ment of study plots within aerially ma damage classes and the ground plot def liation classification allowed us to m some inferences on damage to the stand well as to individual trees (Wickman 1978a). Rapid salvage logging of the m severely defoliated stands, however, r sulted in the loss of most of our clas (heavy) plots and negated our replicat plot design. Substitute plots, severel defoliated, were established in other areas and used for individual tree ana sis. The growth reductions classified a stand basis reported here were not statistically tested; however, they ar presented for comparisons with earlier reported work on tree mortality and top-kill (Wickman 1978a).

Aerially Mapped Defoliation Classes

Pest managers used four aerially mappe classes to stratify the outbreak. When radial growth for each class was graph (fig. 15a), the heavy, moderate, and l classes of grand fir defoliation had a most identical growth patterns both be and after the outbreak. The very light class, where defoliation was observed in 1973, had a 1-year lag before growt declined; but rate of recovery was sim to the other classes. One reason for t almost identical growth configurations all four classes was that the aerially mapped classes were broadly delineated and contained a mixture of two or thre defoliation classes. The similarity am the aerially mapped defoliation classe was also noted in the summary of tree mortality and top-kill for the outbrea (Wickman 1978a).



re 15a.--*Average radial growth of d fir by aerially mapped defoliation ses.*

Douglas-fir, the differences are more ounced and strongly related to amount efoliation. The pre-outbreak growth best in the very light defoliation s, and growth decline was greatest in moderate defoliation class (fig. 15b).

sample size is tabulated below for species:

	Aerially Mapped Defoliation Classes[2]			
	Heavy	Moderate	Light	Very light
fir	78	176	106	80
as-fir	--	14	12	22

---

ple sizes differ from those on page ecause of plot qualification used for analysis.

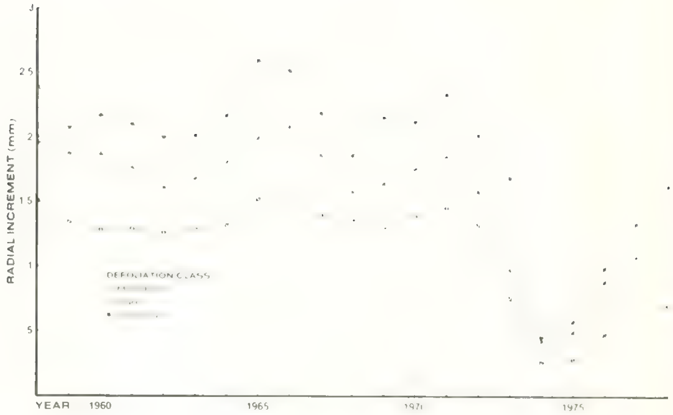


Figure 15b.--Average radial growth of Douglas-fir by aerially mapped defoliation classes.

Ground Plot Defoliation Classes

When the plots are stratified by ground defoliation measurements rather than broadly mapped from the air, some growth relations also differ. The patterns of grand fir growth remain similar for very light, light, and moderate defoliation classes; however, the heavy defoliation class is now distinctly different because only severely defoliated plots are included (fig. 16a). The tabulation of sample trees in the four classes is given below:

	Ground Plot Defoliation Classes[3]			
	Heavy	Moderate	light	Very light
Grand fir	20	283	93	73
Douglas-fir	--	25	13	21

---

[3] Sample size differs from those on page 3 because of plot qualification used for this analysis.

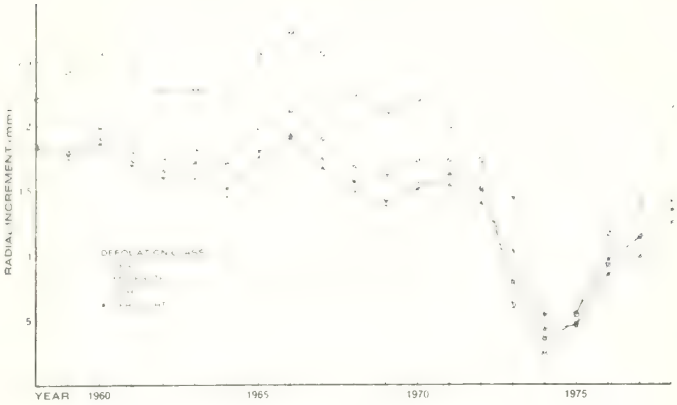


Figure 16a.--Average radial growth of grand fir by ground plot defoliation classes.

In this method of stratification, only 20 severely defoliated grand fir were sampled (compared to 78 trees in the aerially mapped heavy class); but they were selected only from several areas that suffered measured heavy defoliation. With this method of stratification, most of the increase in grand fir sample size occurs in the moderate class, with an increase from 176 trees in the previous analysis to 283 trees in this analysis.

The grand fir in the heavy defoliation class had the best growth rate prior to the outbreak, suffered the sharpest and most severe growth decline, and also recovered most rapidly and completely (fig. 16a). The striking growth recovery of trees in heavy defoliated areas is not unexpected because tree mortality averaged 72 percent of the stand in these areas (Wickman 1978a); consequently, inter-tree competition was drastically reduced.

There is no sample of the heavy defoliation class for Douglas-fir. Growth patterns for light and moderate classes are similar to those for the same classes of grand fir; however, the very light class shows the best pre-outbreak growth (fig. 16b).

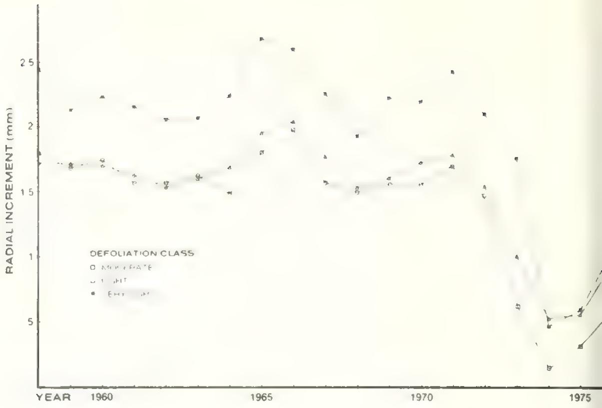


Figure 16b.--Average radial growth of Douglas-fir by ground plot defoliatio classes.

The growth patterns of defoliated star generally conformed to those reported individual trees. Specifically, growth reduction was proportional to degree c defoliation.

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Appendix

Table 2.--Distribution by 1-inch diameters for all defoliated and non-defoliated host trees

D.b.h.	Grand fir		Douglas-fir	
	Defoliated	Non-Defoliated	Defoliated	Non-Defoliated
1	1	0	0	0
2	3	0	0	0
3	8	0	0	0
4	8	0	2	0
5	6	0	0	0
6	13	0	6	0
7	30	0	5	0
8	29	0	3	0
9	35	0	1	0
10	46	1	4	1
11	38	0	4	0
12	29	5	3	3
13	19	0	3	2
14	24	5	2	5
15	15	0	4	1
16	9	9	2	4
17	5	1	1	3
18	15	8	1	8
19	13	1	4	0
20	15	3	0	1
21	8	0	1	0
22	7	1	1	2
23	9	1	0	0
24	5	2	2	0
25	9	0	1	0
26	7	0	2	3
27	8	0	0	0
28	7	1	0	2
29	6	0	1	0
30	2	1	0	0
31	6	0	0	0
32	5	1	0	2
33	7	0	2	0
34	3	0	1	0
35	3	0	0	0
36	6	0	0	0
37	1	0	0	0
38	1	0	0	1
39	1	0	0	0
40	2	0	1	0
41	6	0	0	0
42	2	0	0	0
43	0	0	0	0
44	0	0	0	0
45	0	0	1	0

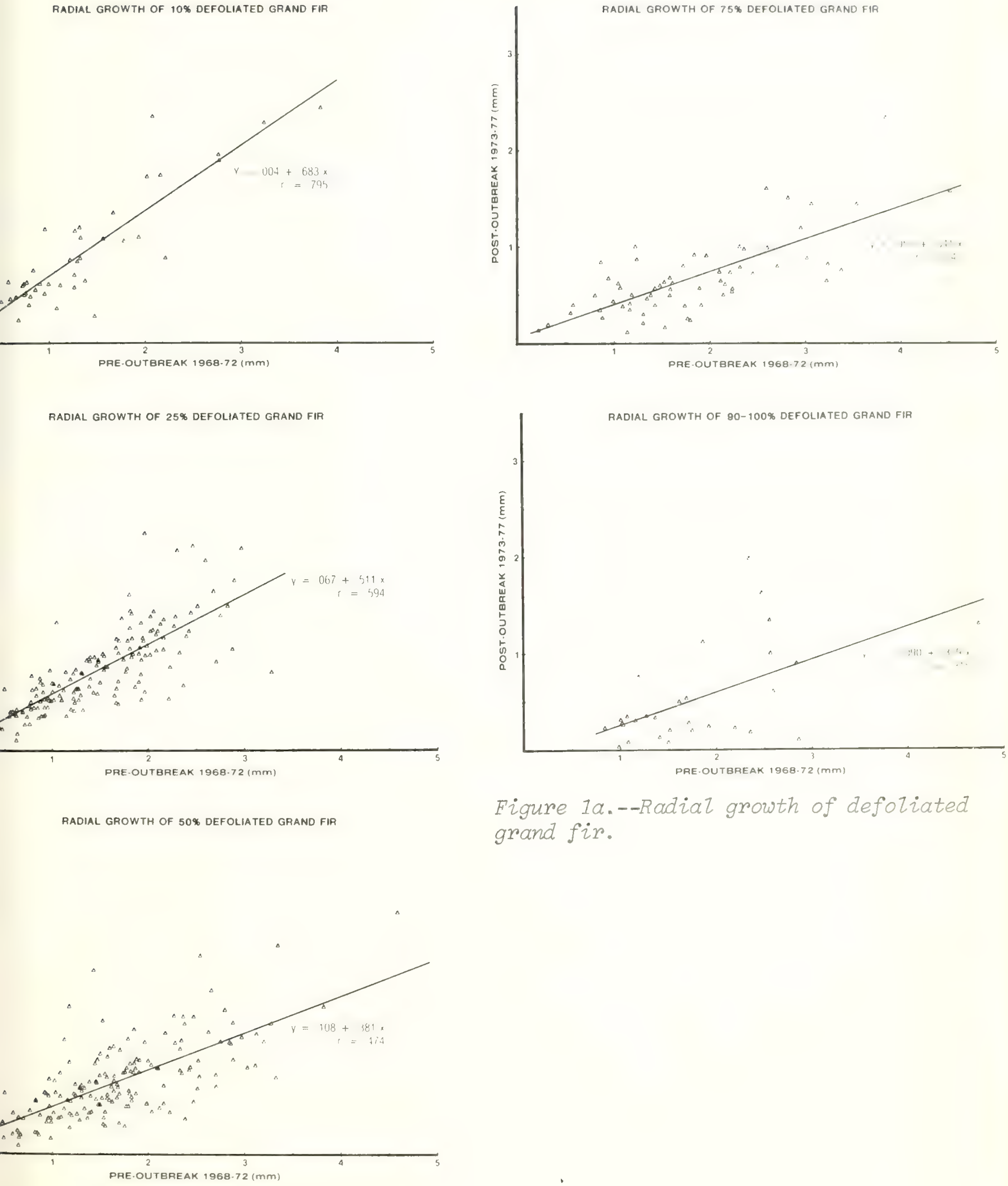
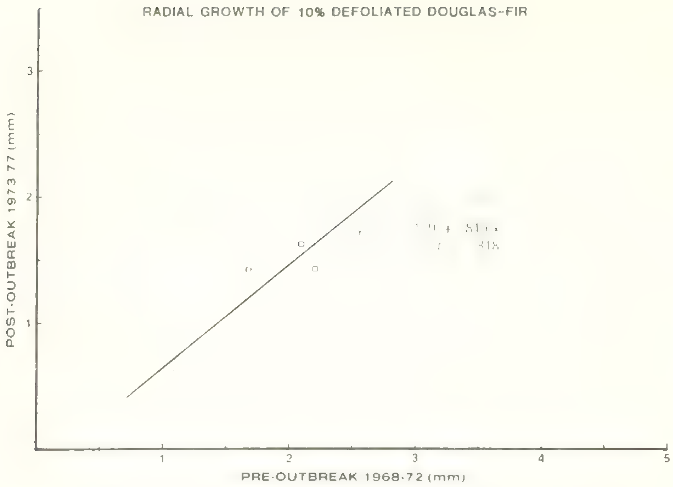
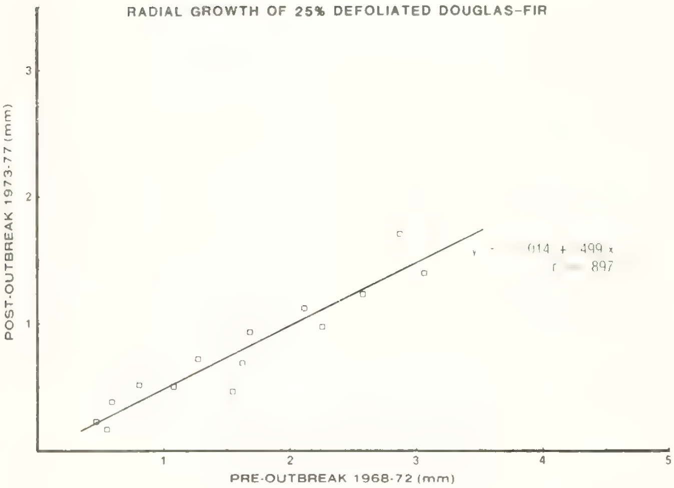
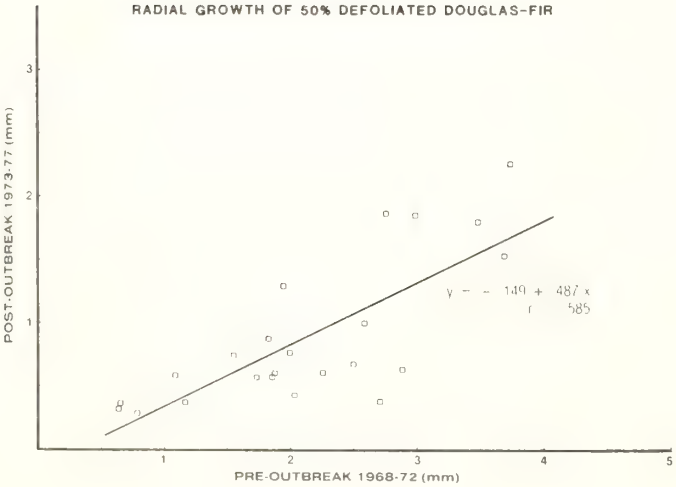
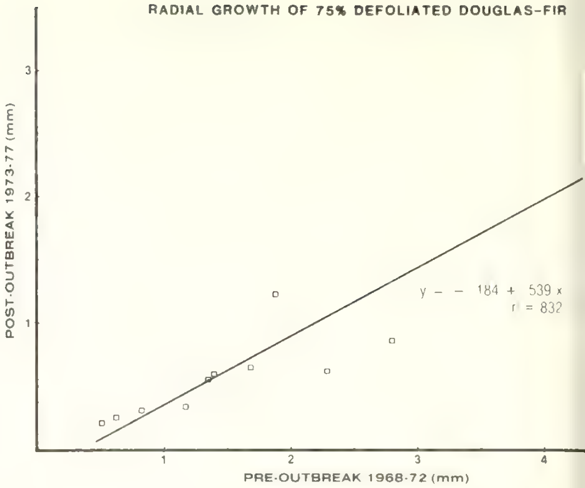


Figure 1a.--Radial growth of defoliated grand fir.


RADIAL GROWTH OF 10% DEFOLIATED DOUGLAS-FIR


RADIAL GROWTH OF 25% DEFOLIATED DOUGLAS-FIR


RADIAL GROWTH OF 50% DEFOLIATED DOUGLAS-FIR


RADIAL GROWTH OF 75% DEFOLIATED DOUGLAS-FIR

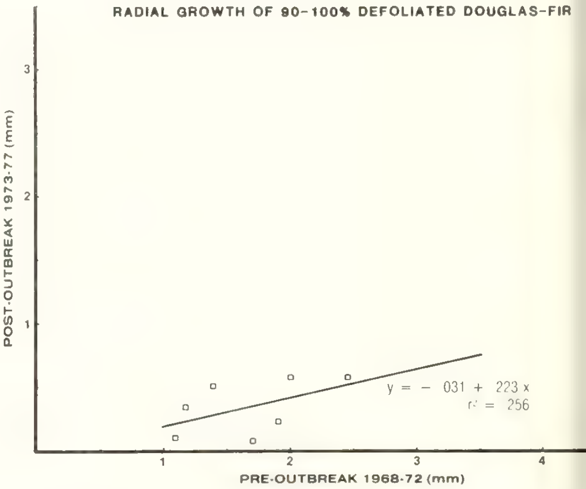
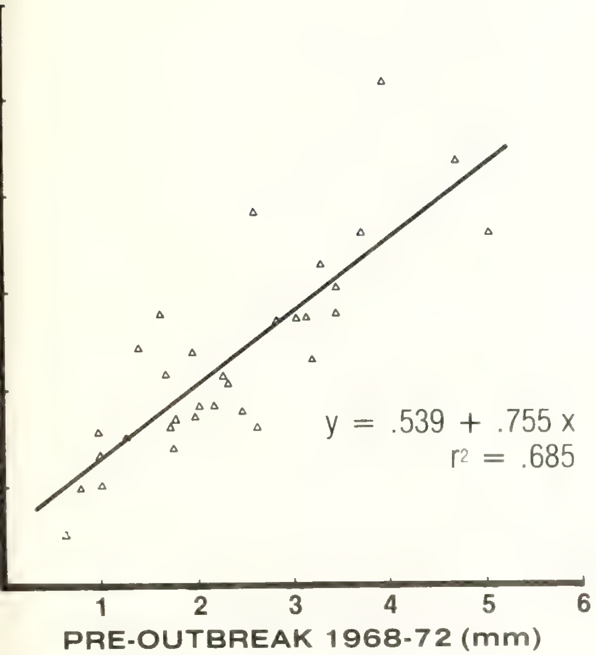

RADIAL GROWTH OF 90-100% DEFOLIATED DOUGLAS-FIR

Figure 1b.--Radial growth of defolia
Douglas-fir.



re 2a.--Radial growth of non-defoliated l fir.

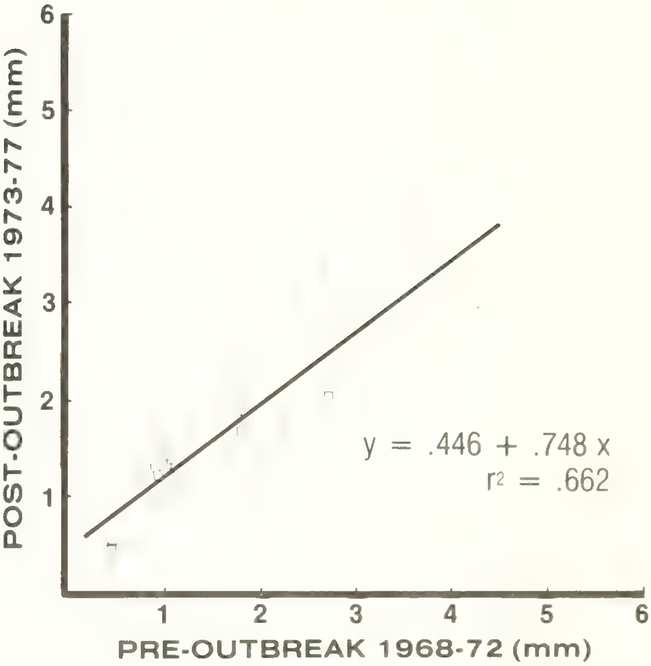


Figure 2b.--Radial growth of non-defoliated Douglas-fir.

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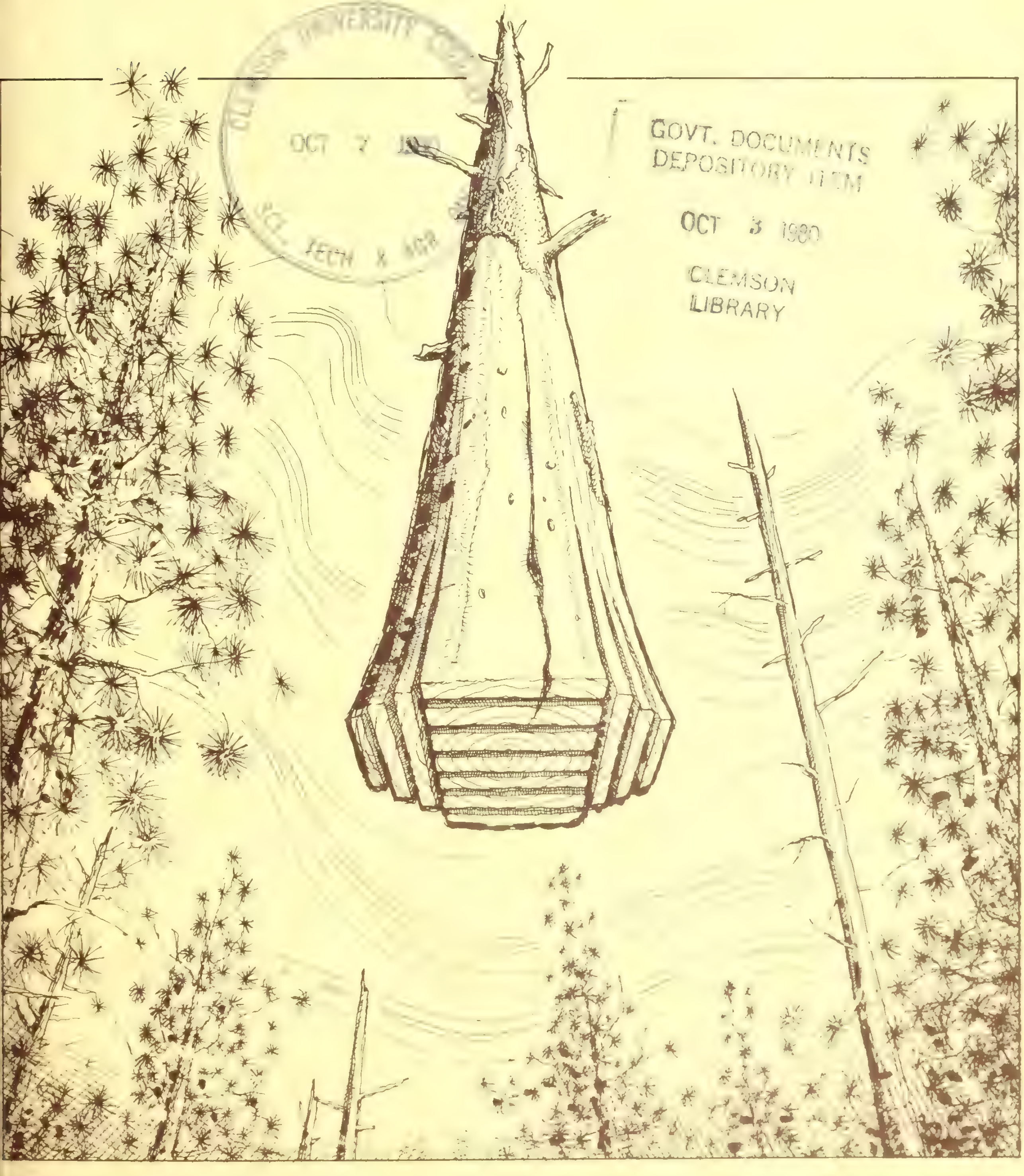
Pacific Northwest
Forest and Range
Experiment Station
Research Paper PNW-270
June 1980

Dead Western White Pine: Characteristics, Product Recovery, and Problems Associated With Utilization

Thomas A. Snellgrove and James M. Cahill



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Authors

THOMAS A. SNELLGROVE is research forest products technologist and JAMES M. CAHILL is research forester at Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Metric Equivalents

1 inch	=	2.540 centimeters
1 foot	=	0.305 meter
1 cubic foot	=	0.028 cubic meter
1 pound	=	0.454 kilogram

reword

research reflects the team effort of
Forest Service scientists and support
f to determine the value of standing
timber. The authors recognize the
ribution of fellow scientists in field
niques and data collection and
ysis. Special credit is given Thomas
ahey for his suggested treatment of
data.

and related research on the potential
product recovery by the Timber Quality
ect of the Pacific Northwest Forest
Range Experiment Station have been
ors in expanded utilization of exten-
volumes of dead softwood timber in
West.

chard O. Woodfin Jr

ARD O. WOODFIN, JR.
ect Leader

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ead Western White Pine: Characteristics, oduct Recovery, and Problems Associated ith Utilization

eference Abstract

llgrove, Thomas A., and James M. Cahill.
). Dead western white pine: characteristics, product recovery,
problems associated with utilization. USDA For. Serv. Res. Pap.
-270, 63 p. Pacific Northwest Forest and Range Experiment Station,
tland, Oregon.

n a western white pine (Pinus monticola Dougl. ex D. Don) tree
s, it undergoes a series of physical changes. The effects of these
nges on product recovery are evaluated. Tabular information and
diction equations provide the tools necessary for using this
ource.

WORDS: Dead timber, lumber recovery, lumber yield, wood utiliza-
n, deterioration (wood), western white pine (dead), Pinus monticola.

esearch Summary

search Paper PNW-270

80

lions of board feet of western white
e (Pinus monticola Dougl. ex D. Don)
killed annually by white pine blister
t (Cronartium ribicola) and the
ntain pine beetle (Dendroctonus
derosae); yet less than 10 percent of
s mortality is currently salvaged.
s report provides tools for resource
agers and the forest products industry
make decisions that can increase
lization of this dead material. It
o provides a framework and guidelines
future research on dead timber.

When a tree dies, it undergoes a series of changes that affect product recovery. These changes include staining, heart checking (splitting), surface checking, weathering, and a general increase in sap rots and wood borer damage. Estimated defect varies substantially, depending on the types of defects and the scaling system used for measurement. Estimates were highest when net Scribner and cubic product potential were the basis for measurement; net cubic showed the lowest defect percents. Net Scribner scale and cubic product potential overestimated the impact of defects on actual product volume; net cubic underestimated the impact.

Even though overrun based on net Scribner is the most common method of representing product recovery in the West, for our study it was the poorest system. Cubic recovery percent and lumber recovery factor best represent the relationship of sawn product volume to log volume. In both systems, when lumber recovery was based on either gross or net cubic scale, recovery decreased from live through the classes of dead logs.

There is a substantial difference in lumber quality between live and dead timber. Live trees produce a high percentage of No. 2 Common and Better and Shop grades, whereas older dead material produces more Nos. 4 and 5 Common. Loss of lumber grade was greatest in highest quality logs because there was more grade to lose. Lumber width also decreased as time since death increased. The average value of lumber produced decreased by about 50 percent from live trees to the oldest dead class. This decrease in value is a reflection of both lower quality lumber and narrower widths.

Losses in log values in dead timber result from combined losses of lumber volume and value. The average value decreases from live logs through the oldest dead logs. Log value also decreases with a decrease in diameter; consequently, both size and deterioration should be considered when values of logs are considered.

As wood dries it becomes more brash; consequently, breakage increases with time since death. The total dollar losses in dead trees are a combination of the losses in lumber volume and value plus the effect of increased breakage.

Six general equations were tested for
predicting product recovery and value
general equation, $\hat{y}=b_0+b_1x_i+b_2/x_i+b_3/$
performed best as measured by R^2 and
standard error of the estimate.

A system based of one live class and
dead classes of material balanced eas
application with refined accuracy. F
this four-class system, the advantage
using classes exceeded the advantage
regressing over diameter, when evalua
on the basis of variation accounted f

troduction

e United States contains an estimated 21 llion board feet of western white pine *inus monticola* Dougl. ex D. Don) wtimber (USDA Forest Service 1973). re than 300 million board feet is killed nually by white pine blister rust *ronartium ribicola*) and mountain pine etle (*Dendroctonus ponderosae*).[1] ss than 10 percent of this annual rtality is salvaged (USDA Forest Service 73).

e opportunity to use this resource pends on several considerations: ailability of raw material, market value d acceptance of products, and total sts of producing the products. Before ese considerations are addressed, wever, we must know the expected product covery from the dead material. We know at there will be losses in product lume and quality of dead trees compared th live trees. We know that breakage creases in felling and handling. kewise, how the raw material is measured ll have an impact on estimated product covery and, therefore, on appraised lues. *This paper is based on a study of stern white pine in Idaho and provides formation and insight into the lationship between product recovery, fects that develop after death of a ee, and scaling systems.* With this formation, resource managers and the rest products industry can make economic cisions about the profitable use of dead stern white pine.

is report will also provide a framework d guidelines for future research on dead mber. The problems we encountered in alyzing results in this study led us to y techniques not commonly used or ported in reports of product recovery. e "Analytical Procedures" for these chniques.

Procedures

Methodology of the study will be discussed in general terms here. More details on the procedures can be found in appendix 1.

Our sample consisted of 194 trees from the Clearwater National Forest in Idaho. Individual trees were selected on the basis of size and stage of deterioration. Efforts were taken to ensure that the sample was representative of the size and quality of western white pine trees from 9- to 34-inch d.b.h. No larger trees were selected; consequently, application of these results should be restricted to this d.b.h. range. Initially, the sample trees were placed in one of six deterioration classes. Subsequent analysis resulted in four deterioration classes:[2]

Live: living green trees
Class I: dead trees (some needle retention)
Class II: dead trees (no needles --90-percent and greater bark retention[3])
Class III: dead trees (no needles--less than 90-percent bark retention in merchantable bole)

Distribution of trees by deterioration class and d.b.h. is shown in table 1.

Unverified data provided by the earwater National Forest, September 4, 73.

[2] A detailed explanation of how the original deterioration classes were selected appears in appendix 1; how we arrived at the final four classes is presented in "Analytical Procedures."

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[3] Percent of bark retention was determined by ocular estimate based on the linear footage of the tree to a 6-inch top. No attempt was made to estimate the bark retained as a percentage of surface area of the tree.

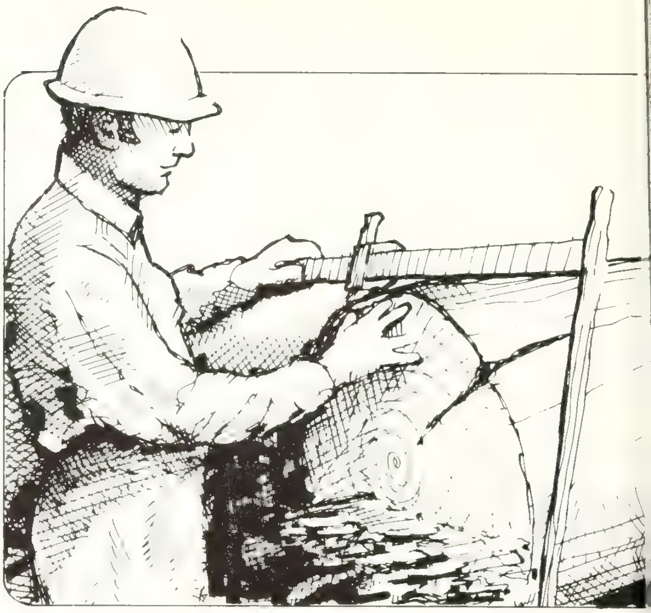
Table 1--Distribution of western white pine sample trees by deterioration class

Deterioration class	Number of trees	D.b.h.	
		Range	Average[1]
		- - - Inches - - -	
Live	17	10-33	22.5
Class I	61	9-29	20.3
Class II	43	9-34	21.2
Class III	73	9-31	20.5
Total or average	194	9-34	20.8

[1] Quadratic mean.

Sample trees were felled and bucked and the subsequent logs identified by tree and log number. Bucked logs were scaled by USDA Forest Service scalers and then processed through a double-cut bandmill. The final lumber tally was equivalent to a shipping tally. The resultant recovery information was the basis for the analysis in this report.

Results and Discussion



Log Information

One objective of this paper is to provide resource managers and the forest products industry with the necessary tools to make economic decisions that will increase the utilization of dead western white pine. primary tool used by both groups is an estimate of product recovery from dead material. To understand product recovery requires an understanding of the relationship between product recovery and two additional factors: the nature of th defects developing after a tree dies and the scaling procedures resulting in estimates of these defects. With an understanding of the relationship between defects, measurements of these defects, and product recovery, users can successfully apply results of the study.

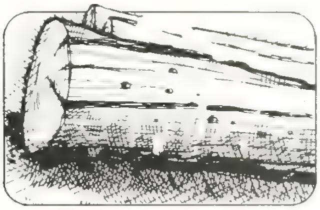
This section will cover:

Defect, with emphasis on development of defect, estimation of defect, and the relationship of these factors to product recovery.

Lumber volume recovery, with emphasis on various methods of presenting recovery ratios.

Lumber yields, with emphasis on lumber grade yields, dimensions, and values.

Log values, which combine the effect of product volume and quality on total log values.



DEFECT

Development of Defect

Physiological defects occur naturally in western white pine trees. In addition to this inherent defect, dead timber is further deteriorated by stain, checks,[4] sap decay, insect damage, and weathering.[5]

When a tree dies, it undergoes a series of changes that may affect the volume and quality of products (figs. 1-5). Western white pine sapwood stains immediately. Also, the tree begins drying which eventually sets up stresses that are released in the form of splits in the bole of the tree. As the tree dries, the wood also loses plasticity and becomes more brash (Wangaard 1950, Panshin and DeZeeuw 1964). At later stages of deterioration, surface checking, weathering, sap rot, and damage from wood borers increase and can render the outer portion of the tree unusable for products. Wright and Harvey (1967) show graphically and discuss similar deterioration in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco).

Deterioration is controlled by environmental influences, such as precipitation, elevation, exposure, slope, and soil. These influences control moisture and temperature conditions, hastening or slowing the rate of deterioration. Not only do moisture and temperature conditions vary from area to area, they also vary up and down the bole of a dead tree. Moist stream bottoms, south exposures, and high elevation have a different effect on deterioration than do exposed ridgetops, north exposures, and low elevations. Basal portions of trees and trees retaining bark present different conditions than tops and trees devoid of bark. When considering two main forms of deterioration--checking and sap decay--we can generalize that any set of conditions promoting drying will increase checking and retard fungal activity. The opposite will be true for trees or sections of trees retaining moisture. Stain appeared to be reasonably constant throughout all the dead trees.

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[4] Checks are splits in the bole of a tree caused by differential drying stresses.

[5] Weathering is general deterioration of the surface of a tree primarily caused by checking and oxidation.

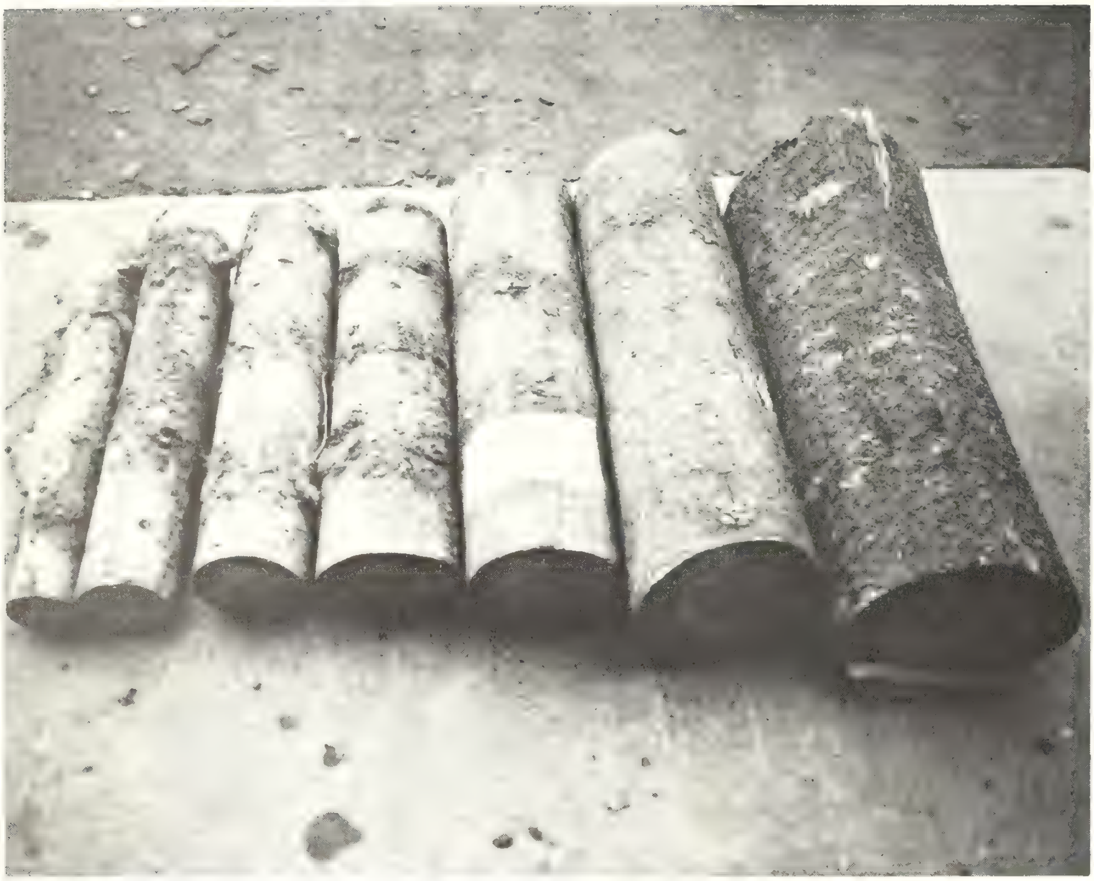


Figure 1.--Typic live western whi pine bolts.

The relationship of environmental factors to deterioration is complex, and it was not in the scope of this study to analyze environmental factors. Since all these conditions can occur over the range of a single timber sale, understanding the basic relationships between environmental factors and deterioration is as important as the specific rates of deterioration.

Defect Estimation

Estimation of defect varies substantiall depending on the scaling system used. This variation is a function of both the types of defects and the vagaries of the measurement system. We will show defect percents based on three methods of estimation and explain why these estimat vary. We will also point out likely reasons for the general increase in defe in logs from dead trees compared with lo from live trees.

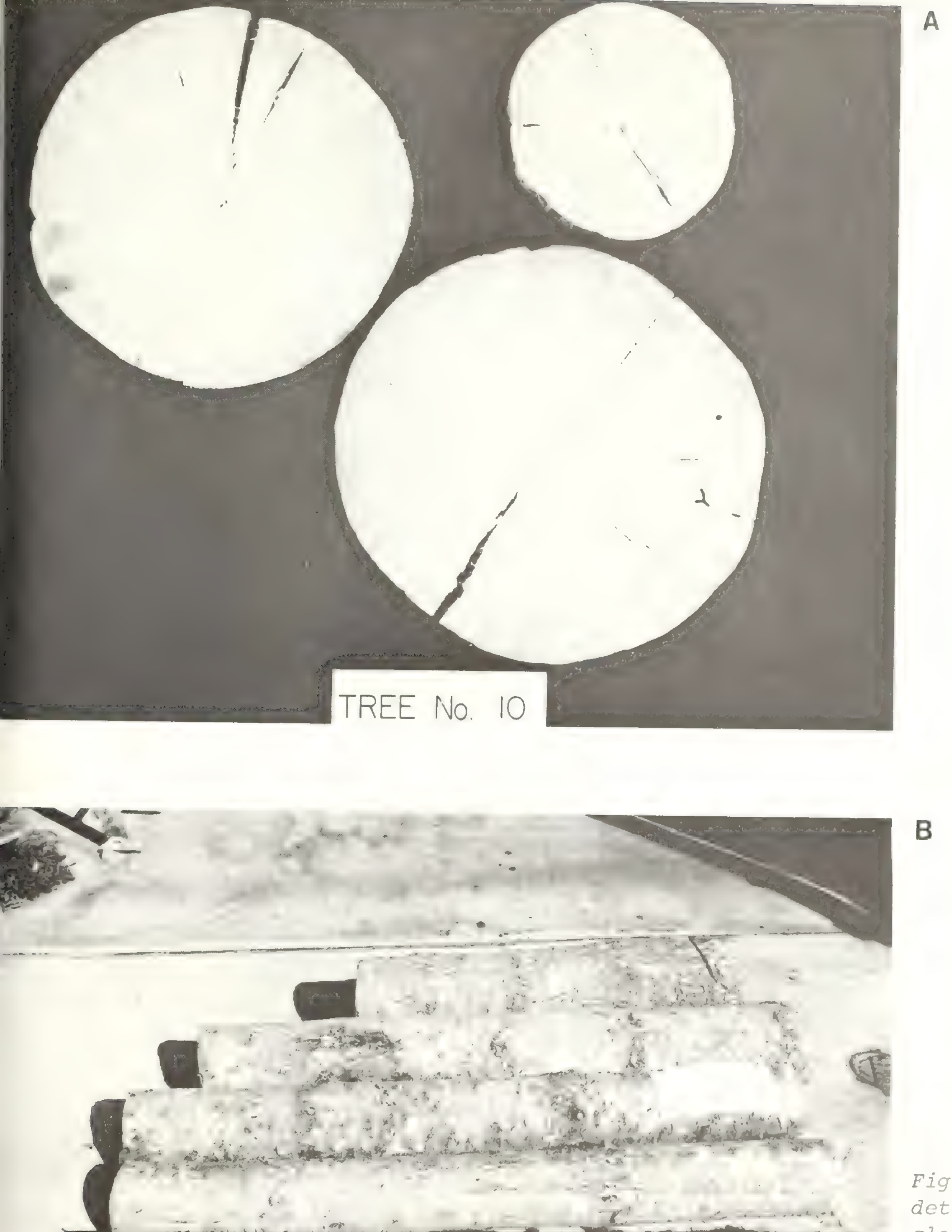


Figure 2.--Typical deterioration of class I western white pine bolts and disks: A, shows shows initial checking in the disks. B, shows little sloughing of bark on the bolts even though the bark has broken from the cambium.

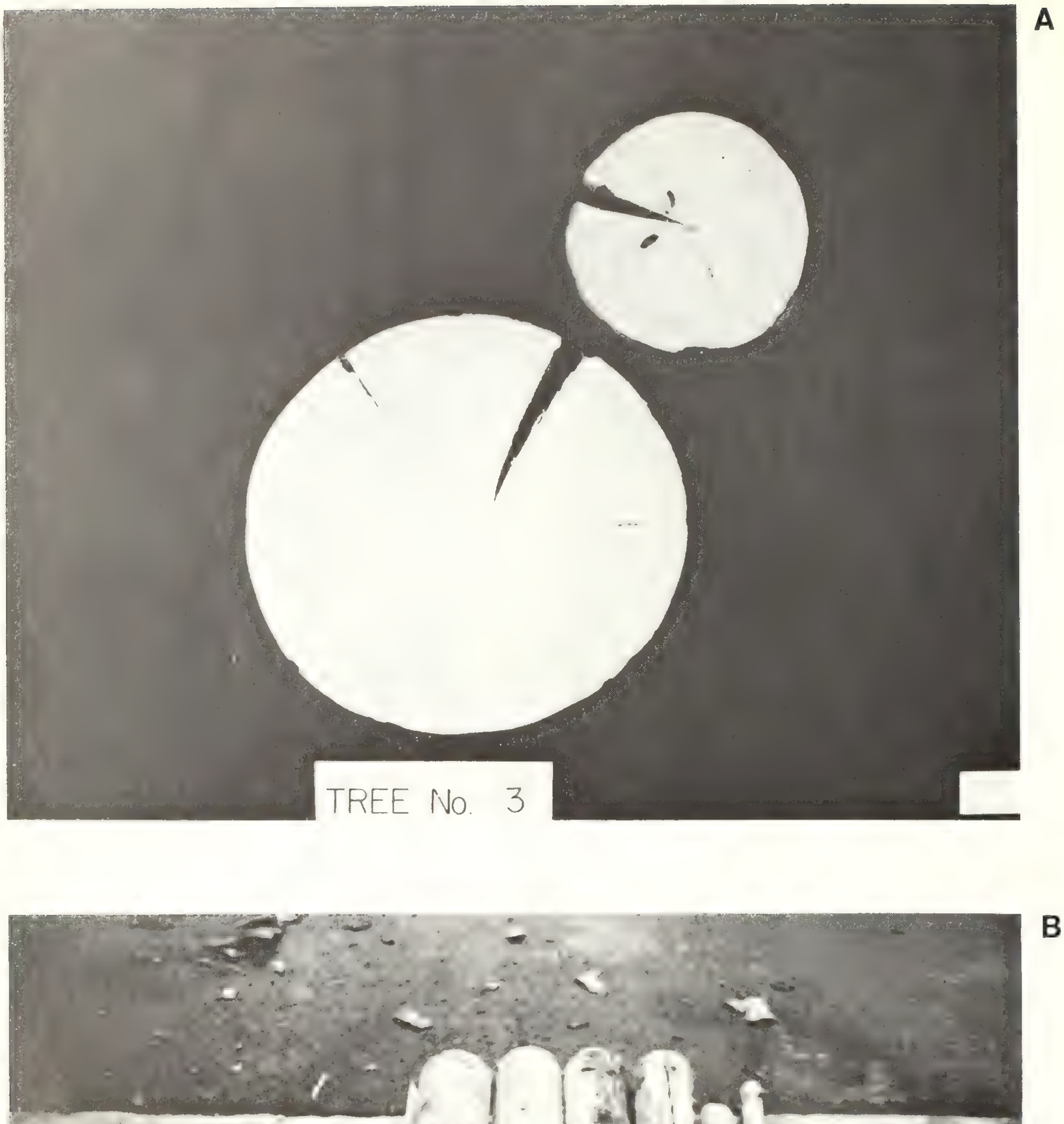


Figure 3.--Typica deterioration of class II western white pine bolts and disks: A, shows expanded width of checks in disks, but there is little surface deterioration on the oute portions of the disks. B, shows bark beginning to slough.

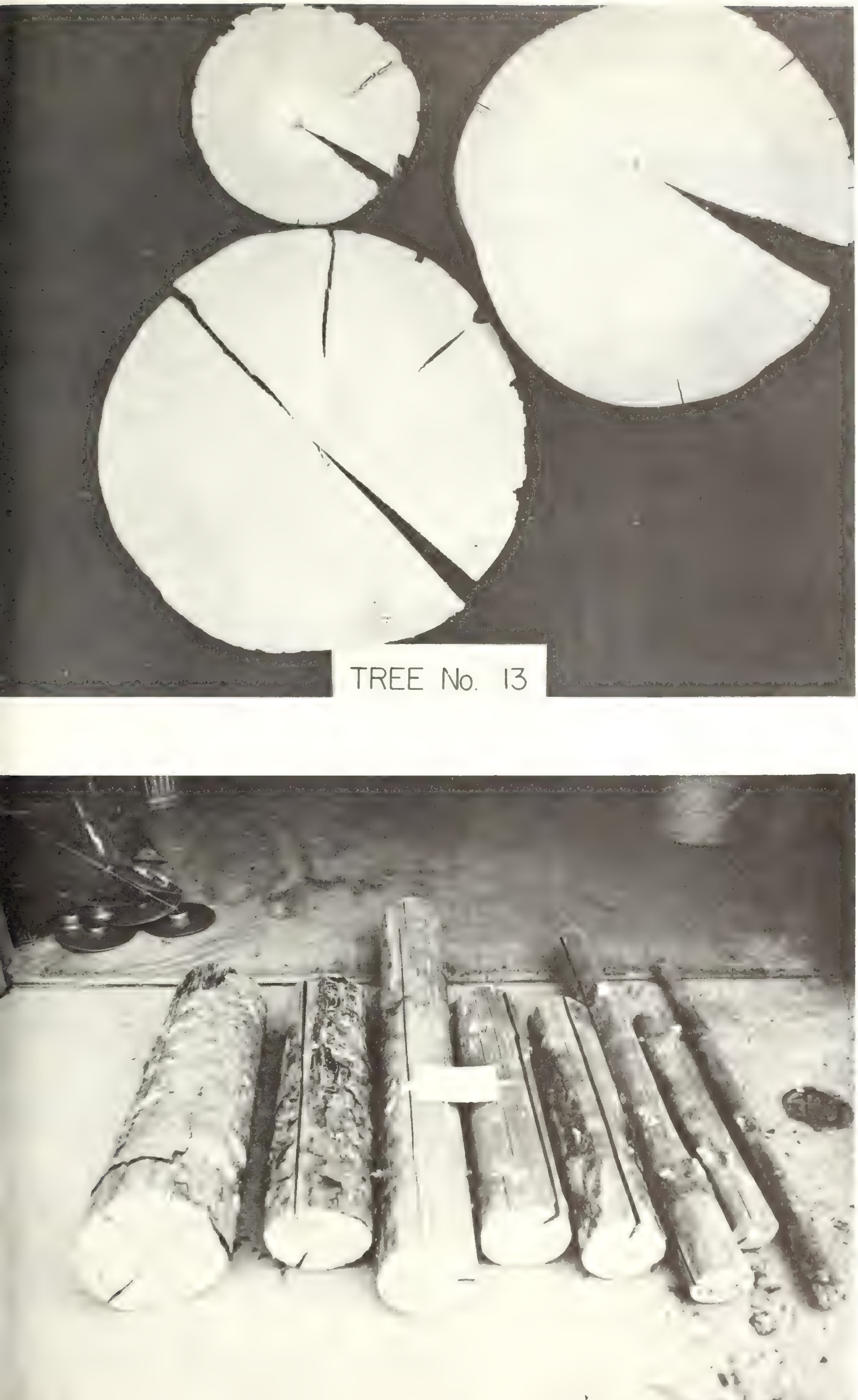


Figure 4.--Typical deterioration of class III western white pine bolts and disks: A, disks show little change in primary checking relative to class II, but surface deterioration from weathering, checking, oxidation, and sap rots are evident. B, bolts show absence of bark.

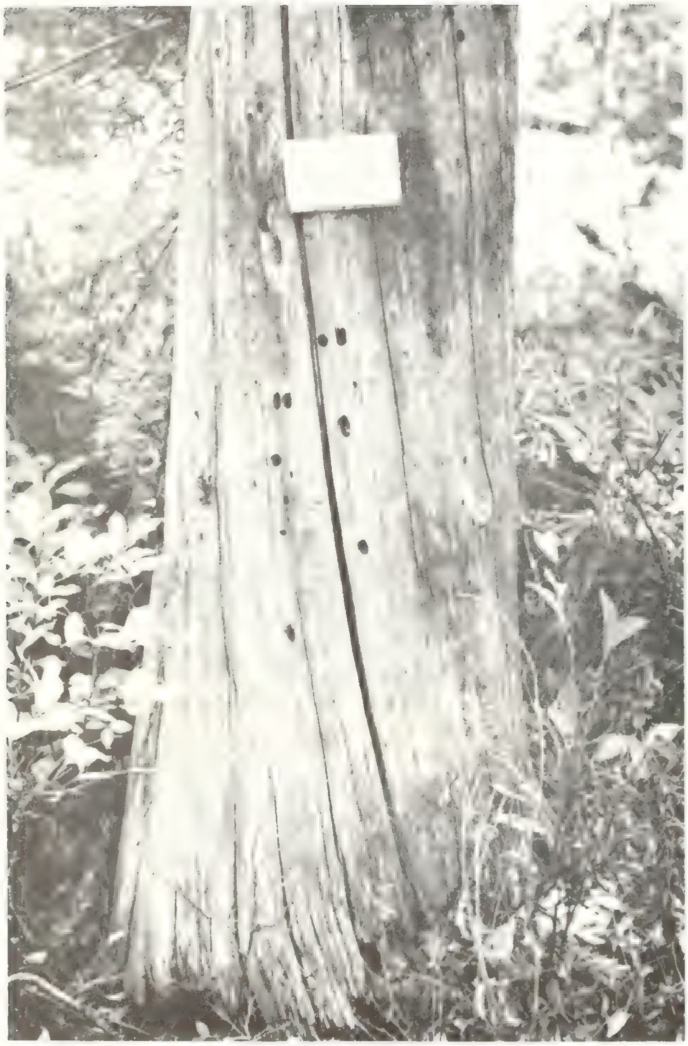


Figure 5.--Typical deterioration in standing class III western white pine tree (same as fig. 4). Note wormholes, spiral checking, and general deterioration of the surface.

Table 2 shows defect percents based on n Scribner scale, net cubic scale, and product potential cubic scale. Definitions and procedures for applying these scales are shown in appendix 1.

It is apparent from table 2 that there i a substantial difference in defect depending on how it is estimated. Each scaling system has a different purpose. The purpose of each system will explain differences between methods of estimatin defects:

Net Scribner reduces estimates of board-foot recovery for defects that are supposed to reduce lumber tally volume.

Net cubic reduces estimates of logs for voids, soft rots, and charred wood. It intended to predict the volume of a log that is suitable to produce a solid chip It does not reduce volumes for such defects as sweep, crook, shake, checks, splits, incipient decay, or certain advanced decays, such as white speck (Fomes pini).

Product potential cubic is similar to ne Scribner scale in that it reduces estimates of log volume for defects that are supposed to reduce lumber tally volume; however, it is based on cubic rather than board-foot volume.

We can now show why the estimates of defect in table 2 increase in each deterioration class within each system. Figures 1-5 pictorially show these change

Net Scribner. The increase from 6.7 to 48.7 percent represents deductions made for checking. Deductions for continued checking plus the onset of sap rots are responsible for the increase from class I to class II logs. These defects plus heavy sap decay and weathering contribute to the high defect in the class III sampl ble 2--Defect expressed as a percent of gross Scribner scale and gross cubic scale r woods-length logs of western white pine[1]

terioration class	Number of logs	Net Scribner defect[2]	Net cubic defect[3]	Product potential cubic defect[3]
		- - - - - - - - Percent	- - - - - - - -	
ve	53	6.7	0.9	8.2
ass I	200	48.7	3.0	39.5
ass II	132	79.0	5.2	59.8
ass III	214	93.8	11.6	80.4
Total or average	599	67.8	6.4	55.8

Defect percent is shown as arithmetic average adjusted to a common diameter base tween classes. It is based on regression analysis. The formula used to calculate fect percent is (gross scale minus net scale/gross scale) (100).

Based on woods-length logs as scaled by USDA Forest Service scalers applying tional Forest Service Log Scaling Handbook rules as of 1974.

Based on woods-length logs as scaled by USDA Forest Service scalers applying the oposed National Forest Service Cubic Scaling Handbook rules as of June 1974. ameters recorded in accordance with cubic scaling handbook; length is actual log ngth to nearest 1/10 of a foot.

t cubic. Since net cubic does not nsider checks as deductions, the defect rcents are lower than for Scribner. ey ranged from 0.9 percent for the live mple to 11.6 for the class III logs. e differences in defect percent between asses is primarily due to the inception sap decays plus weathering in the class and III logs.

oduct potential cubic. The high timates of defect in this scaling system ow much the same pattern as net Scribner ale, and the reasons for the increases estimates of defects are essentially e same as for Scribner.

We have established in table 2 that estimates of defect differ according to the system used for estimation. We also know that defect percents increased from live logs through the dead classes. We will now discuss how these estimates of defects relate to product recovery.

Relationship of Defect, Scale, and Product Recovery

For our purposes, estimates of defects are most important in terms of product recovery; product recovery can only be explained in terms of how the logs were measured. The estimate of defect which is deducted from total gross scale is one of the major variables affecting the accuracy of product estimates. This section illustrates the relationship of product recovery to defect and scale.

Estimates of defects are generally expressed in terms of defect percent (table 2). Product volume, however, is actually predicted from and should be correlated with the percentage of the log that is sound. Percent sound is the complement of defect percent; e.g., 30-percent defect can be shown as 70 percent sound.

To illustrate the relationship of defect to product recovery, we will compare scalers' estimates of sound log volumes to actual change in product recovery. There should be a relationship between the predicted soundness of logs and how much lumber is actually recovered.

Product recovery used for this comparison is cubic recovery percent calculated as (cubic volume of lumber/gross cubic volume of log)(100).

Table 3 shows the cubic recovery percent and the percent sound for the four class of logs. It is apparent in table 3 that product recovery decreases from live log through the classes. Estimated percent sound also decreases within each scaling system. Whether these estimates of soundness correspond to actual changes i volumes of products is not apparent.

The relationship between actual change i product recovery relative to the change percent sound is shown in table 4. An explanation of how these changes are calculated is shown in the footnotes of table 4.

Table 3--Comparison of product recovery by deterioration class to soundness of white pine logs as estimated by 3 scaling systems

Deterioration class	Cubic recovery[1]	Estimated sound[2]		
		Net Scribner	Net cubic	Product potential cubic
		Percent		
Live	44.6	93.3	99.1	91.8
Class I	41.1	51.3	97.0	60.5
Class II	36.4	21.0	94.8	40.2
Class III	31.4	6.2	88.4	19.6

---

[1] Based on gross cubic volume and shown as an arithmetic average adjusted to a common diameter base between classes.

[2] The complement to the defect percent (100 minus defect percent) shown in table 2.

.e 4--Change in product recovery relative to change in soundness by deterioration
;s for western white pine logs

rioration :lass	Change in[1/] actual volume of product	Change in estimated soundness[2/] Net Scribner	Net cubic	Product potential cubic
		Percent		
[3/]	0	0	0	0
s I	-7.8	-45.0	-2.1	-34.1
s II	-18.4	-77.5	-4.3	-56.2
s III	-29.6	-93.4	-10.8	-78.6

sed on change in percent of gross cubic recovery from table 3. The decrease in uct recovery from live to class I is calculated as (44.6-41.1/44.6)(100) = 7.8 ent.

sed on change in estimate from table 3. The decrease in percent sound from live lass I for net Scribner is calculated as: (93.3 - 51.3)/(93.3)(100) = 45.0 percent.

ve logs used as a base for comparison.

e 4 shows that net Scribner and uct potential overestimate the impact efects on product volume, whereas net c underestimates the impact. For ance, product volume for class II logs eased by 18.4 percent, yet estimated dness of the same logs decreased by percent for net Scribner and 56.2 ent for product potential. On the r hand, soundness based on net cubic eased by 4.3 percent, indicating that defect deduction was less than the al change in product volume.

s obvious that none of the systems rately predicted the loss of product me. We can look at the systems vidually to explain why the estimates incorrect:

Net Scribner.--The 45-percent decrease in predicted soundness from live to class I was primarily due to checking. The 7.8-percent decrease in product volume indicates that checking did not have this great an impact on lumber recovery. There was a reduction in volume because of checking, but the technique used in Scribner scale to estimate this loss results in deductions that exceed the actual loss. We encountered little spiral checking in this study; but where spiral checks occur a larger loss of lumber volume can be expected. Checking plus sap rots and weathering causes the high defect in the class II and III logs. Again, Scribner scaling techniques result in deductions that exceed actual product loss.

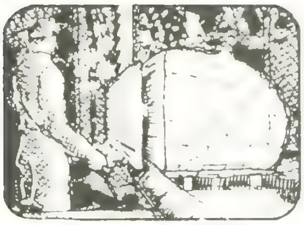
Net cubic.--Net cubic is intended to predict the volume of a log that is suitable to produce a solid chip. Since net cubic does not consider checks as deductions, the reduction in percent sound is less than for Scribner. Even in the class III logs, estimated soundness was only reduced by 10.8 percent. This 10.8 percent corresponds to a 29.6-percent loss in product volume. Whereas Scribner overestimates the impact of defects on product volume, net cubic underestimates the impact.

Product potential cubic.--As with Scribner, this scale reduces estimates of log volumes for defects that are supposed to reduce lumber tally volume. The large reductions in estimated percent sound in this scaling system show much the same pattern as net Scribner scale (see table 4). Even though the percent sound estimates are closer to actual product volume loss, they still exceed the actual loss. As with Scribner, this scale overestimates the impact of checks on product volume.

Table 4 shows that the most accurate estimates of percent sound relative to product volume lie between net cubic and product potential cubic. For example, the change in product volume for class I logs was a minus 7.8 percent, whereas the change in percent sound was a minus 2.1 percent for net cubic and minus 34.1 percent for product potential cubic. This relationship also holds true for the other classes. In all cases, estimates of percent soundness based on Scribner techniques were the poorest and those based on net cubic were the best.

We have confined our discussion to relating product recovery to estimates of percent sound. What if the impact of defect is disregarded? Product recovery can be based on gross estimates as well a net in either Scribner or cubic scale. I we included the gross estimates, there wo be five systems of measuring volume of lo input: gross and net Scribner; and gross net, and product potential cubic. Any system used to measure volume of log inpu should be able to predict product volume in terms of lumber tally. An analysis of how well each system predicted lumber tally is presented in detail under "Analytical Procedures."

Our intention in this section of the pape is to illustrate the relationship of product recovery to defect and scale. We have shown how estimated defect relates t actual changes of product volume and why the estimates differ from the actual change. Since product recovery is based on the scaled volumes of logs, understanding the differences between the scaling systems allows the reader to interpret the product recovery data presented in the next section.



RODUCT RECOVERY

ead timber undergoes a series of physical nanges that affect product recovery. One esult of these changes is a loss of roduct volume relative to live timber; .e., for the same volume of logs sawn, ess lumber will be produced from dead ogs.

ne volume of products recovered in elation to log input volume is important o all mill operators. For a given size nd species, cost of manufacturing logs aries little, yet product volume ecovered can vary substantially. This ariation in product volume recovered is ccentuated when dead timber is milled.

here are a number of ways of expressing ne relationship of product volume to log olume: recovery ratio (overrun), cubic ecovery percent, or lumber recovery actor. These product recovery ratios are efined as:

Recovery ratio (overrun) = board feet f lumber tally per board foot of net log cale expressed as a percent. It is equal o overrun plus 100 percent. Although ecovery ratio has traditionally been xpressed as a percent of net Scribner cale, it can also be expressed as a ercent of gross Scribner scale.

Cubic recovery percent = cubic feet of ough green lumber per cubic foot of log nput. It can be expressed as a percent f the gross, net, or product potential stimates of the cubic volume of a log. ubic recovery percent can be based on urface dried lumber as well as rough reen lumber.

Lumber recovery factor = board feet of lumber tally per cubic foot of log volume. As with cubic recovery percent, log input volume can be expressed either as gross, net, or product potential estimates.

Tables 5 and 6 present estimates of product recovery as a function of various scaling systems and can be used for general comparisons. Table 5 presents the various scaling systems and table 6 shows the product recovery. A more detailed breakdown of these results, including lumber yields by diameter, deterioration class, and scaling system is presented in appendix 2, tables 14-18.

Recovery Ratio (Overrun)

The most commonly used recovery ratio in the forest products industry is overrun plus 100 percent. Recovery ratios based on net Scribner scale are shown in table 6. Logs from live trees yielded a 109-percent[6] recovery ratio based on net scale. This compares with recovery ratios of 178, 351, and 1,010 percent for classes I, II, and III logs. The high recovery ratios for the dead logs reflect excessive deductions in the scaling system. Net Scribner requires severe deductions for checking in the logs, when, in fact, lumber is actually produced around these checks. Often arbitrary deductions must be applied by the scaler to defects that have little or no effect on product recovery.

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[6] The recovery ratios presented here are based on weighted class averages rather than arithmetic averages. Reasons are detailed in table 6.

Table 5--Summary of lumber tally and log scale by deterioration class for western white pine logs

Deterioration class	Number of logs	Lumber tally		Scribner scale[1]		Cubic scale[2]		
				Gross	Net	Gross	Net	Product potentia
		Board feet	Cubic feet[3]	--Board feet--		- - - - - -Cubic feet- - -		
Live	53	11,731	1,065	10,970	10,430	2,000	1,963	1,808
Class I	200	32,932	2,872	32,730	18,510	5,934	5,711	3,837
Class II	132	21,287	1,854	23,010	6,070	4,071	3,689	1,809
Class III	214	29,490	2,539	36,515	2,920	6,552	5,612	1,491
Total	599	95,440	8,330	103,225	37,930	18,557	16,975	8,945

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[1] Woods-length logs as scaled by USDA Forest Service scalers applying National Forest Service Log Scaling Handbook rules as of 1974.

[2] Woods-length logs as scaled by USDA Forest Service scalers applying the proposed National Forest Service Cubic Scaling Handbook rules as of June 1974. Diameters recorded in accordance with Cubic Scaling Handbook, length recorded as actual log length to nearest 1/10 of a foot.

[3] Based on rough green dimensions of lumber.

ble 6--Summary of product recovery by deterioration class for western white pine logs[1]

eterioration class	Recovery ratio[2]		Cubic recovery			Lumber recovery factor		
	Gross, Scribner	Net, Scribner	Gross	Net	Product potential	Gross	Net	Product potential
	- - - - - - - - - - -	-	Percent	- - - -	- - - -	Board feet per cubic foot		
ve	104	109	44.6	44.8	55.1	5.0	5.0	7.4
ass I	93	[3]	41.1	42.4	[3]	4.7	4.9	[3]
ass II	82	[3]	36.4	39.2	[3]	4.2	4.5	[3]
ass III	76	[3]	31.4	37.1	[3]	3.7	4.3	[3]
erage	85	[3]	36.9	40.0	[3]	4.2	4.6	[3]

Product recovery presented as arithmetic averages adjusted to a common diameter
etween classes.

Recovery ratio is equal to overrun plus 100.

Not applicable; arithmetic average for the dead logs cannot be calculated because of
arge number of logs with zero net Scribner scale and zero product potential cubic
cale. Weighted averages for net Scribner scale are: live, 112 percent; class I, 178
ercent; class II, 351 percent; class III, 1,010 percent. Weighted averages for
oduct potential cubic scale are: live, 59 percent; class I, 75 percent; class II,
2 percent; class III, 170 percent. Weighted averages for product potential lumber
ecovery factor are: live, 6.5 board feet/cubic foot; class I, 8.6 board feet/cubic
ot; class II, 11.8 board feet/cubic foot; class III, 19.8 board feet/cubic foot.

ecovery ratio can be expressed in gross
s well as net Scribner scale (table 6).
hen recovery ratio was based on gross
cribner, the percents decreased from 104
or the live to 76 for the class III logs.
ecovery ratios based on gross Scribner
re seldom used, even though this is a
ore realistic picture of what happens to
roduct recovery.

Cubic Recovery

Cubic recovery percent is the proportion of the log recovered as lumber. It can be expressed as a percent of the gross, net, or product potential estimates of the cubic volume of a log.

Figure 6 shows the relationship of cubic recovery percent to log diameter for both gross and net cubic scales by deterioration class. Table 6 shows cubic recovery percent averages by class. The percent of a log converted to lumber decreases as time since death increases.

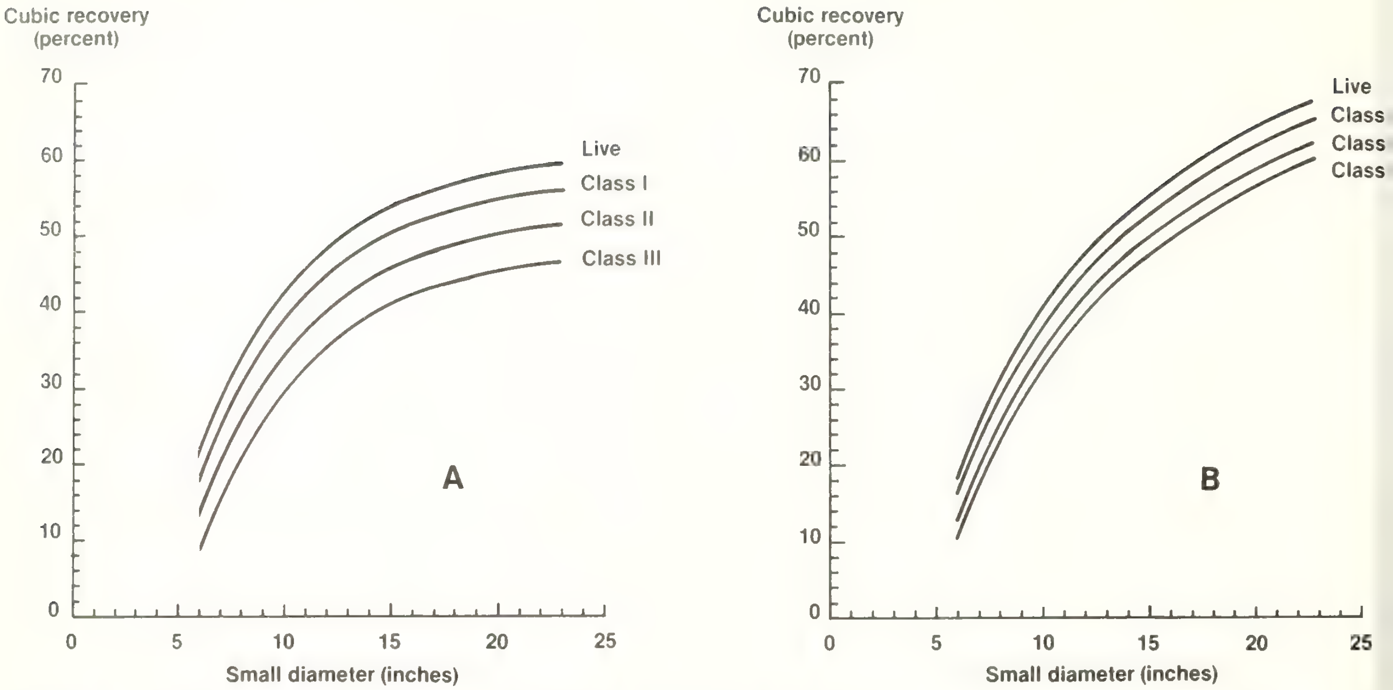

Figure 6.--Percent of cubic log volume produced as rough green lumber by log diameter and deterioration class, western white pine:

A, gross volume; statistical information--

$\hat{y}(\text{live})=100.24-0.71994(D)-593.18(1/D)+865.77(1/D^2)$,

$\hat{y}(\text{class I})=96.62-0.71994(D)-593.18(1/D)+865.77(1/D^2)$,

$\hat{y}(\text{class II})=91.99-0.71994(D)-593.18(1/D)+865.77(1/D^2)$, and

$\hat{y}(\text{class III})=87.09-0.71994(D)-593.18(1/D)+865.77(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 12.57 and 0.482.

B, net volume; statistical information--

$\hat{y}(\text{live})=83.80+0.29235(D)-546.02(1/D)+854.69(1/D^2)$,

$\hat{y}(\text{class I})=81.45+0.29235(D)-546.02(1/D)+854.69(1/D^2)$,

$\hat{y}(\text{class II})=78.20+0.29235(D)-546.02(1/D)+854.69(1/D^2)$, and

$\hat{y}(\text{class III})=76.11+0.29235(D)-546.02(1/D^2)+854.69(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 13.87 and 0.484.

There were highly significant differences in intercepts between deterioration classes, but differences between slopes were not significant.[7] Notice that separation between classes was reduced when net cubic scale was used as the basis for measuring volume of log input.

In recently killed trees (class I), dryin checks were the primary cause of the reduction in lumber volume. The stress caused by drying appeared most often to b released in one primary check, but frequently one or two smaller checks also occurred. Spiral checks were not prevalent in the study; but when they occurred, the losses of lumber volume were greater. The impact of drying checks on lumber yield is also illustrated and iscussed in the section "Lumber imensions." Additional losses in the lder dead material were due mainly to eathering, sap rots, and borers. igures 1-5 illustrate these losses.

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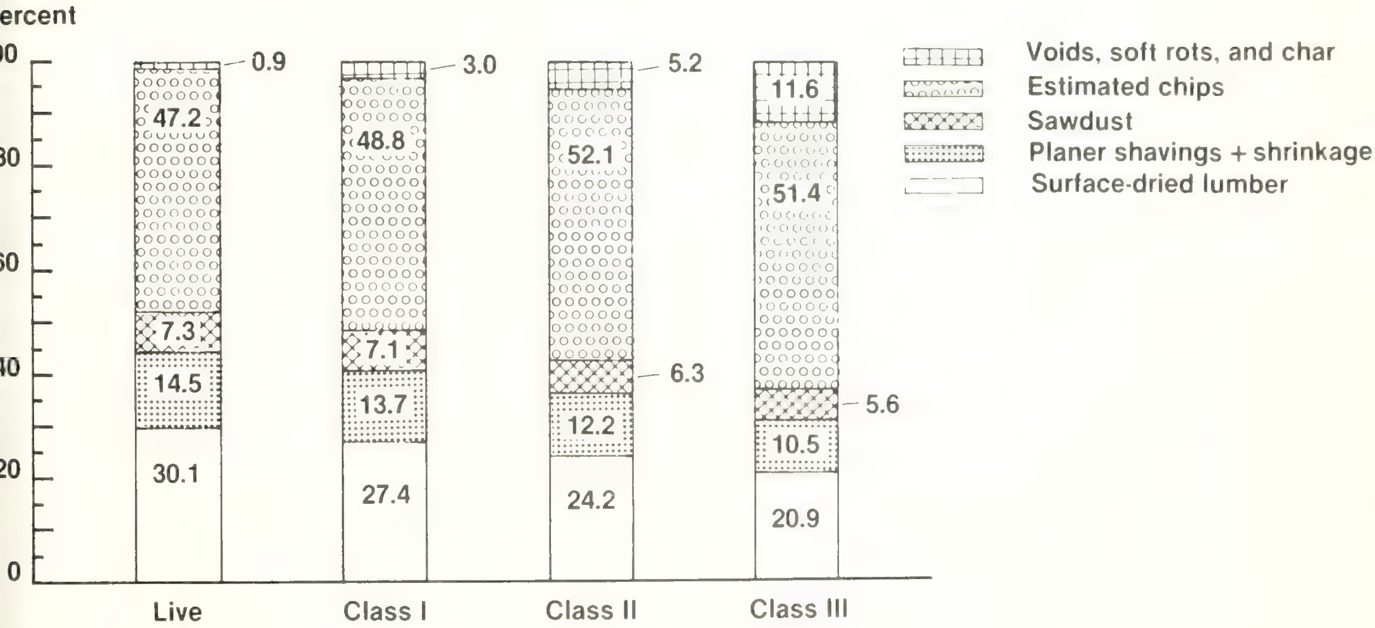
[7] Throughout this paper, highly significant implies the 0.01 level of probability; significant, the 0.05 level.

he cubic volume of all components of a og can be delineated and expressed as a ercent of the total log volume (fig.7). he rough green cubic recovery is ndicative of the lumber volume a log is apable of producing. The surface dry ubic recovery is the same lumber as the ough green minus the loss from shrinkage nd surfacing. The relationship between ough green cubic and surface dry is an indication of a mill's efficiency. For example, 41.1 percent of the log volume in class I was converted to rough green lumber, and 27.4 percent was ultimately produced as surface dry lumber. Thus, about 67 percent (27.4/41.1 = 66.6) of the rough green lumber ended up as surface dry lumber. This relationship will be reasonably constant for all classes. Fahey and Woodfin (1976) and Dobie and Wright (1970) give detailed explanations of these relationships.



igure 7.--Cubic volume of log components expressed as a percent of total gross log ubic volume by deterioration class, western white pine. Note that surfaced dried umber plus planer shavings and shrinkage equal rough green lumber.

After the lumber is removed, the remaining volume of the log can be separated into sawdust volume, chippable volume, and voids. Sawdust and chippable volumes are calculated; voids are the difference between gross cubic and net cubic scale.

Lumber Recovery Factor (LRF)

Lumber recovery factor is board feet of lumber tally per cubic foot of log volume. As with cubic recovery, an LRF estimate can be based on either gross cubic, net cubic, or product potential estimates. LRF and cubic recovery percent are nearly identical estimates of product volume; the difference is that lumber output is measured in board feet in LRF and in cubic feet in cubic recovery percent. There are minor differences between the two as the actual lumber size varies by dimension.

Average LRF's for the various deterioration classes of logs are shown in table 6. The curved relationship of LRF over log diameter is shown in figure 8. The curves follow the same patterns as those for cubic recovery in figure 6. As with the cubic recovery curves, there wer highly significant differences between class intercepts and no significant difference between slopes. Explanation o differences in product recovery between live and dead logs in terms of LRF is the same as for cubic recovery.

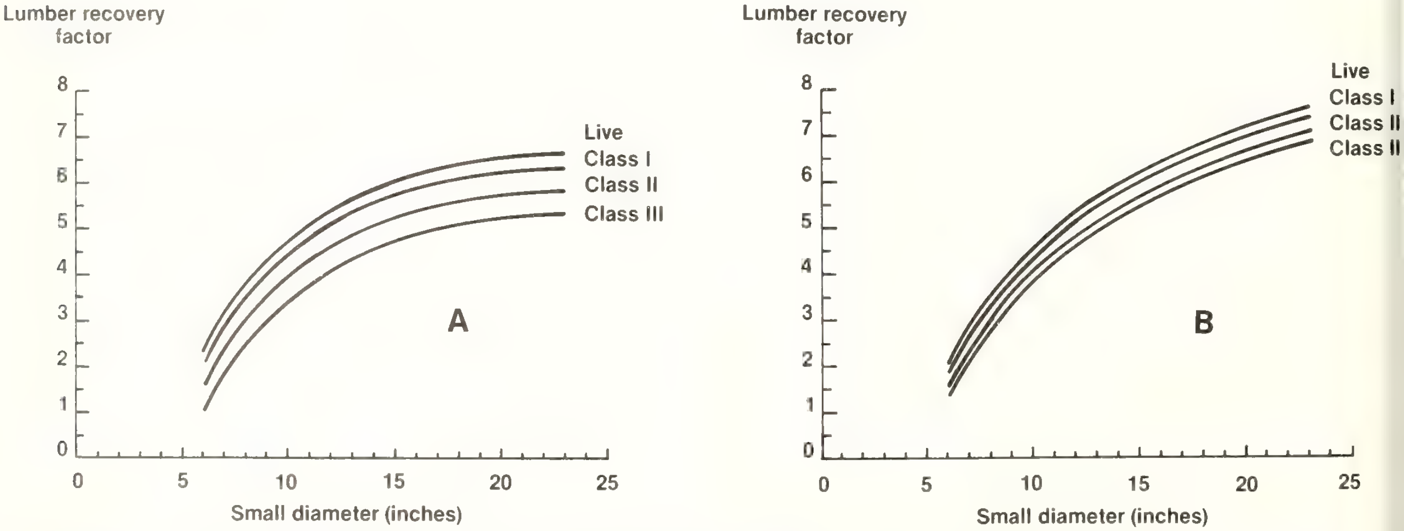


Figure 8.--Lumber recovery factor: Board-foot lumber tally per cubic foot of log by diameter, western white pine.

A, gross volume; statistical information--

$\hat{y}(\text{live})=11.38-0.0861(D)-67.69(1/D)+98.72(1/D^2)$,

$\hat{y}(\text{class I})=11.09-0.0861(D)-67.69(1/D)+98.72(1/D^2)$,

$\hat{y}(\text{class II})=10.60-0.0861(D)-67.69(1/D)+98.72(1/D^2)$, and

$\hat{y}(\text{class III})=10.06-0.0861(D)-67.69(1/D)+98.72(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 1.40 and 0.482.

B, net volume; statistical information--

$\hat{y}(\text{live})=9.53+0.0290(D)-62.67(1/D)+98.57(1/D^2)$,

$\hat{y}(\text{class I})=9.39+0.0290(D)-62.67(1/D)+98.57(1/D^2)$,

$\hat{y}(\text{class II})=9.59+0.0290(D)-62.67(1/D)+98.57(1/D^2)$, and

$\hat{y}(\text{class III})=8.85+0.0290(D)-62.67(1/D)+98.57(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 1.56 and 0.504.

hip and Sawdust Recovery

ven though markets for chips are ndependable, chip yields are necessary to etermine the total value of logs. awdust is a residue generally used as ogged fuel; but with the cost of energy, nis product is becoming more important.

olumes of chips are determined by subtrac- ing the rough green cubic volume of umber and calculated volume of sawdust rom the gross volume of logs. Any defect or voids, soft rots, and char (i.e., net ubic deductions) are also removed from ne gross volume. Sawdust volumes are ased on average saw kerf and the number nd sizes of boards produced. Appendix 1 ocuments the procedures used in deter- ining yields from chips and sawdust.

ne trend of chip and sawdust yields xpressed as a percent of the volume of ogs is shown in figure 7. Because the ercent of the log produced as rough-green umber decreased as time since death ncreased, we assumed that the percent of nips would increase. Chip yields were bout 47 percent for live logs; 49 percent or class I; 52 percent for class II; and 1 percent for class III. The decrease in lass III log volume recovered as chips is robably due to loss from voids, soft ots, and char (fig.7). The impact of the oids, soft rots, and char is also eflected in class I and II logs. The ncrease in chip yields for those logs was ot as high as expected, considering the ecrease in lumber output.

Chip yields were converted from volume to weight since values are generally expressed in dollars per bone dry unit.[8] The average pounds of chips per gross and net cubic foot of log input are shown in the following tabulation:[9]

Deterioration class	Cubic log scale Gross	 Net
	(pounds/cubic foot)	
Live	11.6	11.7
I	11.8	12.2
II	13.2	13.8
III	13.2	14.6

These averages will give a general idea of the relationship between classes. The effect of diameter on chip yields, however, was so important that we suggest the curves shown in figure 9 be used.

Figure 9 shows the relationship of chip yield to log diameter. The higher yields in the smaller diameter logs were expected since chip yields are strongly affected by lumber yields. The curves for chips are the complement to the cubic lumber recovery curves; e.g., smaller logs produced less lumber, thus more chips per unit of log volume. The effect of producing a higher percentage of the volume of small logs in slabs and edgings results in these curve shapes.

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[8] A bone-dry unit is a quantity of wood residue that would weigh 2,400 pounds at 0-percent moisture content.

[9] Average as used here is an arithmetic average adjusted to equalize diameter differences between classes.

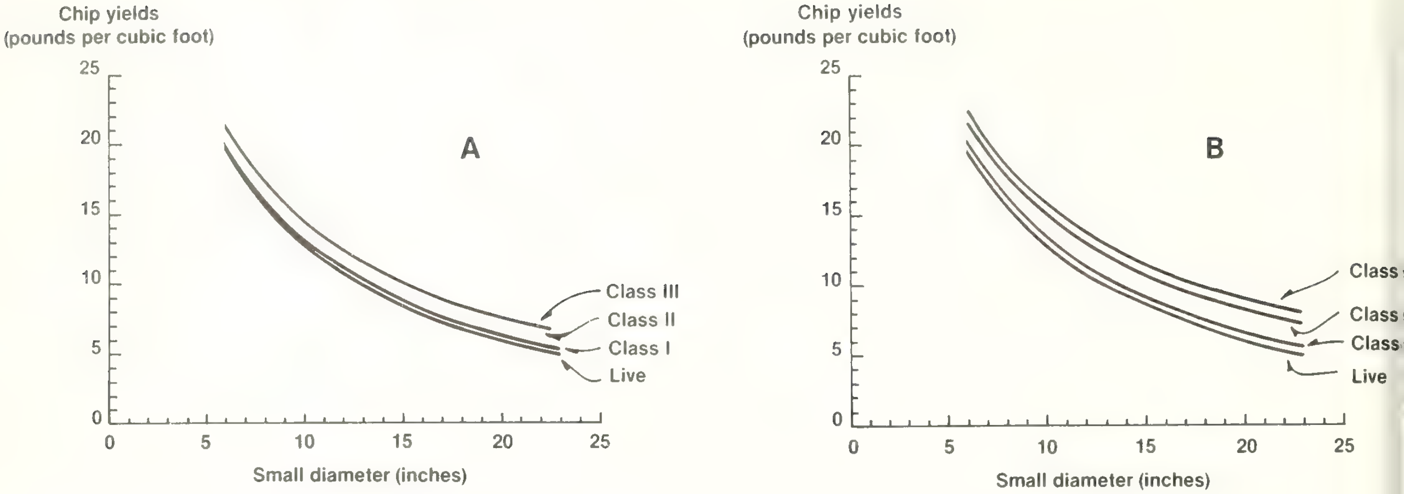


Figure 9.--Yields of ovendry chips per cubic foot of log input over diameter, western white pine:

A, gross volume; statistical information--

$\hat{y}(\text{live})=-2.98+0.008(D)+189.0(1/D)-326.0(1/D^2)$,

$\hat{y}(\text{class I})=-2.69+0.008(D)+189.0(1/D)-326.0(1/D^2)$,

$\hat{y}(\text{class II})=-1.29+0.008(D)+189.0(1/D)-326.0(1/D^2)$, and

$\hat{y}(\text{class III})=-1.33+0.008(D)+189.0(1/D)-326.0(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 3.87 and 0.533.

B, net volume; statistical information--

$\hat{y}(\text{live})=-2.26+0.002(D)+180.0(1/D)-301.0(1/D^2)$,

$\hat{y}(\text{class I})=-1.71+0.002(D)+180.0(1/D)-301.0(1/D^2)$,

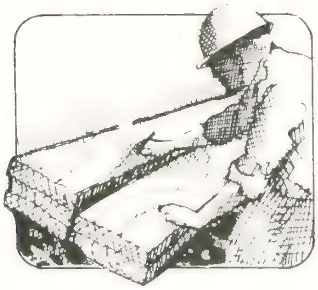
$\hat{y}(\text{class II})=-0.13+0.002(D)+180.0(1/D)-301.0(1/D^2)$, and

$\hat{y}(\text{class III})=0.64+0.002(D)+180.0(1/D)-301.0(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 3.91 and 0.529.

Covariance analysis indicated a highly significant difference between the classes, yet in reality the advantage gained in explained variation, by separating into classes, was small. Expressed as pounds of chips per gross cubic-foot input (fig.9A), the difference was primarily between two groups represented by live logs plus class I, and class II plus class III logs. Expressed as a percent of net cubic-foot input (fig. 9B), the differences between classes were more uniformly distributed. The impact that chip yields have on log values is shown in the section, "Log Value."

Sawdust yields expressed as a percent of log input volume are shown in figure 7. Sawdust yields were 7.3, 7.1, 6.3, and 5.6 percent of log volume for live through class III logs. The average was about 2 pounds of sawdust per gross or net cubic foot of log input for all classes combined



MBER YIELDS

addition to changes in volumes of oducts recovered from dead timber, oduct quality (grade) changed even more astically. Changes occurred in lumber mensions as well as in lumber quality. ese changes in grade and dimension termine lumber value. Differences in erage values of lumber are tested in the mber value section.

Lumber Grade Yields

A comparison of the percentages[10] of lumber grades by grade groupings emphasizes another difference between live and dead timber (fig. 10). A pattern emerges in which the live trees produce a high percentage in No. 2 Common and Better (the higher grades), and the oldest dead trees produce a high percentage in No. 4 and 5 Common. Even in the oldest dead categories there was more No. 3 Common and Better than No. 5 Common. The white pine lumber grade yields from green logs in this study are similar to the yields for the live grade 4 logs in a previous study by Plank and Snellgrove (1973).

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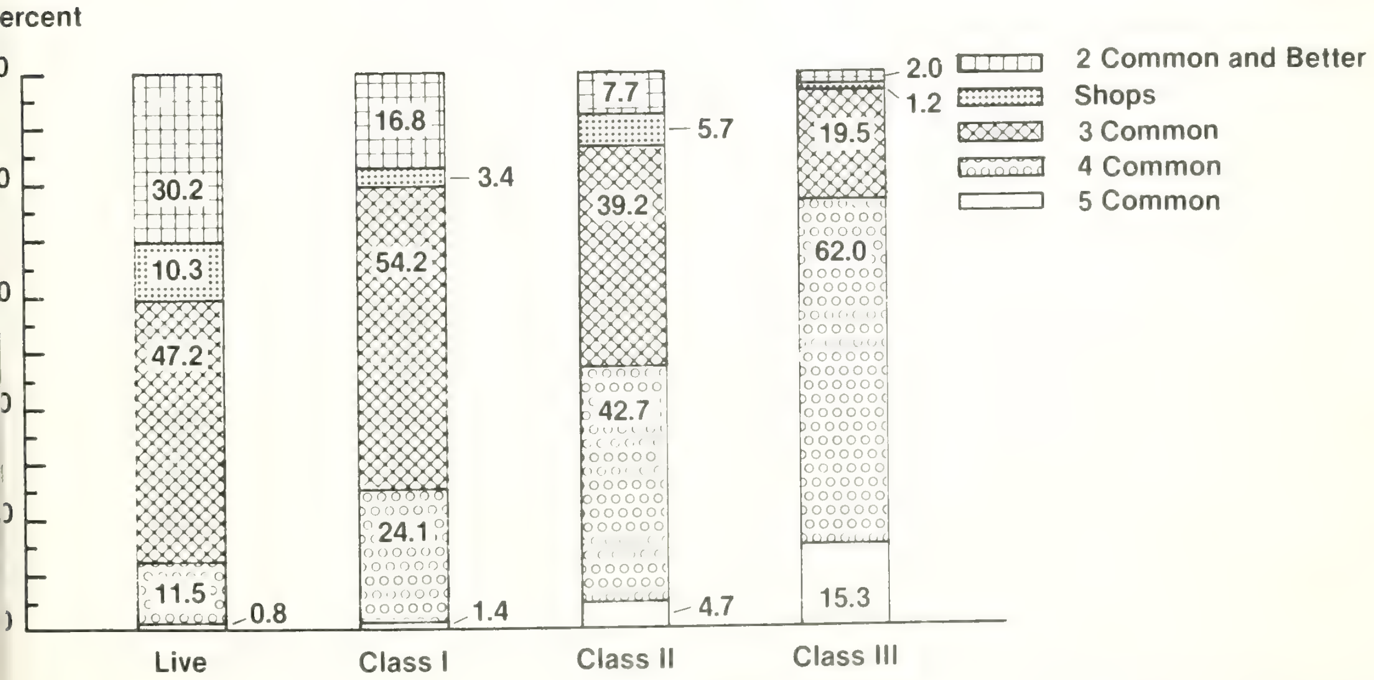
[10] Average percent as used here is a weighted average of each lumber grade by class.



gure 10.--Lumber grade yield as a percent of total lumber tally volume by deterioration ass, western white pine.

Initially, lumber degrade was caused by blue stain and splits due to drying checks. Blue stain dropped lumber from the Shop grades as well as from No. 2 Common and Better down to No. 3 Common. This degrade does not occur in material that produces primarily dimension items. In dimension lumber, items are graded on strength rather than appearance, and stain is not a factor in degrade. Splits caused by drying checks contributed more to loss of volume than to degrade. They generally resulted in narrow boards due to more edging.

Wormholes were present but not prevalent in the dead logs. Even when present, they did not significantly limit lumber grade since they were generally confined to the base of the oldest dead trees. The majority of lumber from the oldest dead trees had already been degraded to No. 3 or 4 Common, and these grades allow some holes. As with splits, sap rots contributed more to loss of lumber volume than to degrade.

When lumber grade yields from dead timber are evaluated, there is another important point to consider--grade loss will be greatest in the highest quality logs. No attempt was made to sample the truly high quality white pine (large diameter, limb-free trees) in this study. It is a relatively minor component of the resource base and will continue to decrease as a percent of the overall resource. Since this high grade material produces a high percentage of Shops and Selects, the impact of stain degrading the lumber to No. 3 Common assumes even greater importance.

Lumber Dimensions

Most board items are priced by dimension as well as by grade. Consequently, lumbe width will have an impact on the value of the final product. The impact of drying checks on width is illustrated in table 7. The percentage of narrow lumber 6 inches and narrower, increased from 20 percent to 35 percent for the live to class III group. Conversely, the percentage of wide lumber (1 by 10's and 1 b 12's) decreased from live to class III. complete breakdown of lumber yields by dimension and grade is presented in appendix 2, tables 19-23.

There can be a twofold impact from more narrow lumber being produced in dead material: (1) narrow boards are generall worth less; and (2) a large influx of narrow boards, particularly in the lower grades of lumber, could adversely affect marketability of the material.

Table 7--Percentage of western white pine lumber by width and deterioration class

Width	Deterioration class			
	Live	I	II	I
		Percent		
6 inches and narrower[1]	20	24	27	3
8 inches	16	18	18	1
10 inches and wider[2]	64	58	55	5
Total	100	100	100	10

[1] Includes 4- and 6-inch lumber.

[2] Includes 10-inch and 12-inch lumber.

From our observation, the impact of checking is considerably greater when more than one check occurs or when spiral checks are involved. The impact of checking on volume and value is also affected by the type of lumber produced. It is most severe in Board and Shop items where all widths are produced and where wide boards are worth more. The impact on dimension lumber is less because many mills produce primarily narrow widths. Another generalization can be made--the thicker the item produced, the less impact checking will have. A timber, for instance, is more apt to remain intact and retain a higher grade than a board.

Lumber Value Loss

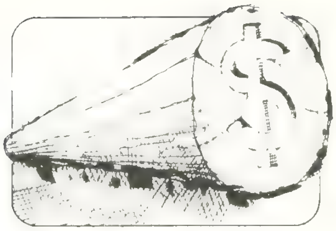
As shown in figure 10 and table 7, lumber grade yields and dimensions varied substantially by deterioration class. The impact of this variation can best be expressed in dollars per thousand board feet of lumber tally ($/MLT) and is shown in the following tabulation:

Deterioration class	Average board value $/MLT	99-percent confidence interval
Live	204.00	±16.00
Class I	160.00	±7.00
Class II	122.00	±7.00
Class III	101.33	±4.00

Dollars per thousand lumber tally is the average value (based on an arithmetic average) of the lumber produced. It does not include the loss of volume. The average value of the lumber decreased from live through the three deterioration classes.

In this study there is virtually no relationship between $/MLT and log diameter. Yet, there is a significant difference in average $/MLT between classes. Variation accounted for in regressing over log diameter was less than 2 percent. On the other hand, about 52 percent of the total variation was accounted for by stratifying the logs in classes. Consequently, we suggest using class averages when estimating lumber values.

The value of the lumber produced varies as lumber price varies. Tables 19-23, which are the percent of total lumber production by grade and dimension, are presented in appendix 2. This information is included to allow the user to apply current prices to the data.



LOG VALUE

We have described the losses from lumber volume and from lumber value; we now need a composite figure to reflect both these losses in logs. Table 8 shows changes in lumber volume and value and several ways of expressing the dollar values. The dollar values depend on how the log volumes are estimated.

In this table, differences in lumber volume are shown in terms of cubic recovery, and differences in lumber value are shown in dollars per thousand board feet lumber tally. Excessive deductions made in net Scribner scale and in cubic product potential scale are reflected by the artificial increase in value of older dead material (see footnotes 2 and 3 of table 8). Values per unit of volume increased as time since death increased--a contradiction to how a scaling and grading system should perform. Log values expressed as dollars per hundred cubic feet gross or net ($/CCF) scale and dollars per thousand board feet gross Scribner scale all decreased as time since death increased.

Figure 11 shows the relationship of $/CC of gross and net scale over log diameter.[11] The solid lines include the combined value of lumber and chips, whereas the dotted lines represent only lumber. The most important aspect of adding chip values relates to the value the marginal log. When chips can be marketed they may be the difference between a log's being profitable or unprofitable.

Figure 12 is the same as figure 11A but shows combined lumber and chip values on It illustrates how figure 11 might be us

Assuming a fixed production cost (loggin and milling) of $70/CCF, we see how much dollar surplus is available for stumpage and profit and risk. A buyer might only be able to allow $17/CCF for stumpage an profit and risk for class II logs in th 19-inch diameter class. On the other hand, about $67 could be allowed for the live logs in the 19-inch diameter class. These values represent the difference between the production cost line and the total value curves for each deterioratio class. Only the 19-inch and larger clas III logs would exceed production costs, whereas 12-inch class II, 8-inch class I and 5-inch live logs would all exceed these hypothetical costs. If the value c chips were removed (as shown in fig. 11), a larger log would be needed to realize profit.

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[11] Comparison of deterioration classes i figure 11 shows a highly significant difference in slopes and intercepts for the curves. The difference in slope was not considered a practical difference eve though it was statistically significant; consequently, a common slope was used for both gross and net figures.

Table 8--Average losses of lumber volume and value and log values by scaling system and deterioration class[1]

Deterioration class	Cubic recovery	Lumber value	Log values by scaling system: Scribner scale, Gross	Scribner scale, Net	Cubic scale, Gross	Cubic scale, Net	Cubic scale, Product potential
	Percent	Dollars/thousand board feet			Dollars/hundred cubic feet		
Live	44.6	204.13	212.87	[2]	103.45	103.88	107.49
Class I	41.1	160.33	149.16	[2]	76.12	78.68	[3]
Class II	36.4	122.49	101.00	[2]	52.54	56.61	[3]
Class III	31.4	101.33	77.18	[2]	37.47	43.66	[3]

---

[1] All averages except dollars per thousand board feet net log scale and dollars per hundred cubic feet product potential are arithmetic averages adjusted to a common diameter base between classes.

[2] Not applicable; arithmetic averages cannot be calculated for the dead logs because of the large number of logs with zero net Scribner scale and zero product potential cubic scale. Weighted averages for net scale are: $240.69, $299.19, $484.93, and $1,043.38 for live logs and classes I, II, and III logs.

[3] Weighted averages for product potential are $107.49, $230.39, $475.97, and $1,295.11 for live logs and classes I, II, and III logs.

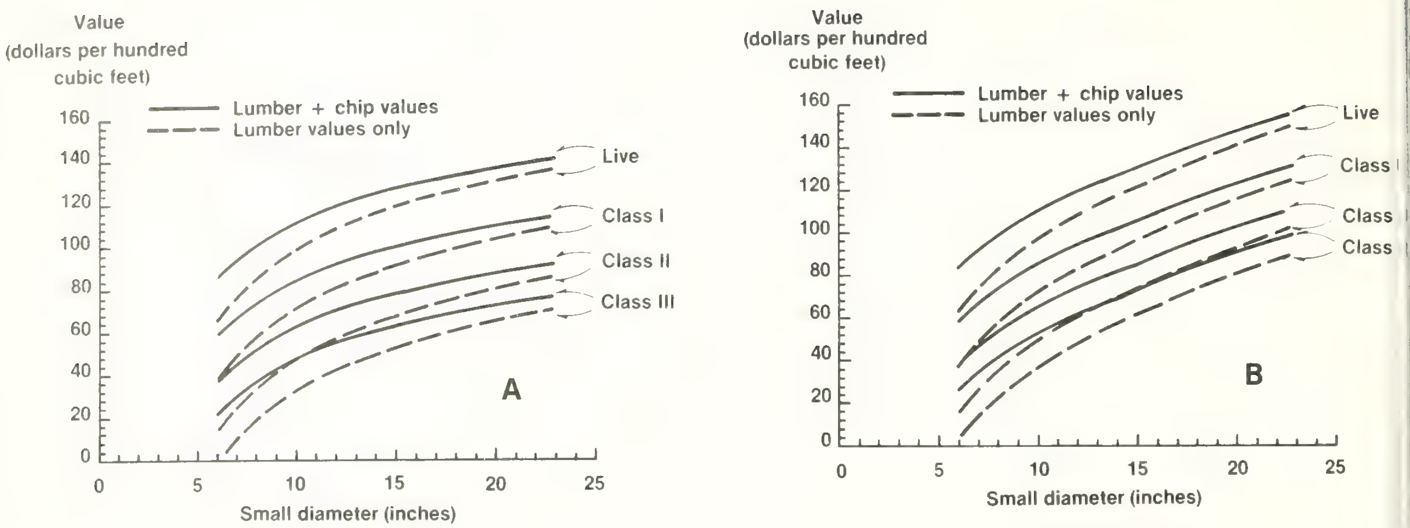


Figure 11.--Values per hundred cubic feet of log volume by diameter and deterioration class, western white pine:

A, gross values; statistical information--

Lumber plus chips:

$\hat{y}(\text{live})=150.23+0.5034(D)-493.22(1/D)+531.7(1/D^2)$,

$\hat{y}(\text{class I})=123.20+0.5034(D)-493.22(1/D)+531.7(1/D^2)$,

$\hat{y}(\text{class II})=101.08+0.5034(D)-493.22(1/D)+531.7(1/D^2)$, and

$\hat{y}(\text{class III})=85.98+0.5034(D)-493.22(1/D)+531.7(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 22.61 and 0.559.

Lumber values only:

$\hat{y}(\text{live})=153.34+0.4948(D)-690.11(1/D)+871.1(1/D^2)$,

$\hat{y}(\text{class I})=126.07+0.4948(D)-690.11(1/D)+871.1(1/D^2)$,

$\hat{y}(\text{class II})=102.42+0.4948(D)-690.11(1/D)+871.1(1/D^2)$, and

$\hat{y}(\text{class III})=87.36+0.4948(D)-690.11(1/D)+871.1(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 24.38 and 0.580.

B, net values; statistical information--

Lumber plus chips:

$\hat{y}(\text{live})=103.17+2.6889(D)-194.47(1/D)-159.0(1/D^2)$,

$\hat{y}(\text{class I})=78.58+2.6889(D)-194.47(1/D)-159.0(1/D^2)$,

$\hat{y}(\text{class II})=58.28+2.6889(D)-194.47(1/D)-159.0(1/D^2)$, and

$\hat{y}(\text{class III})=45.99+2.6889(D)-194.47(1/D)-159.0(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 22.30 and 0.579.

Lumber values only:

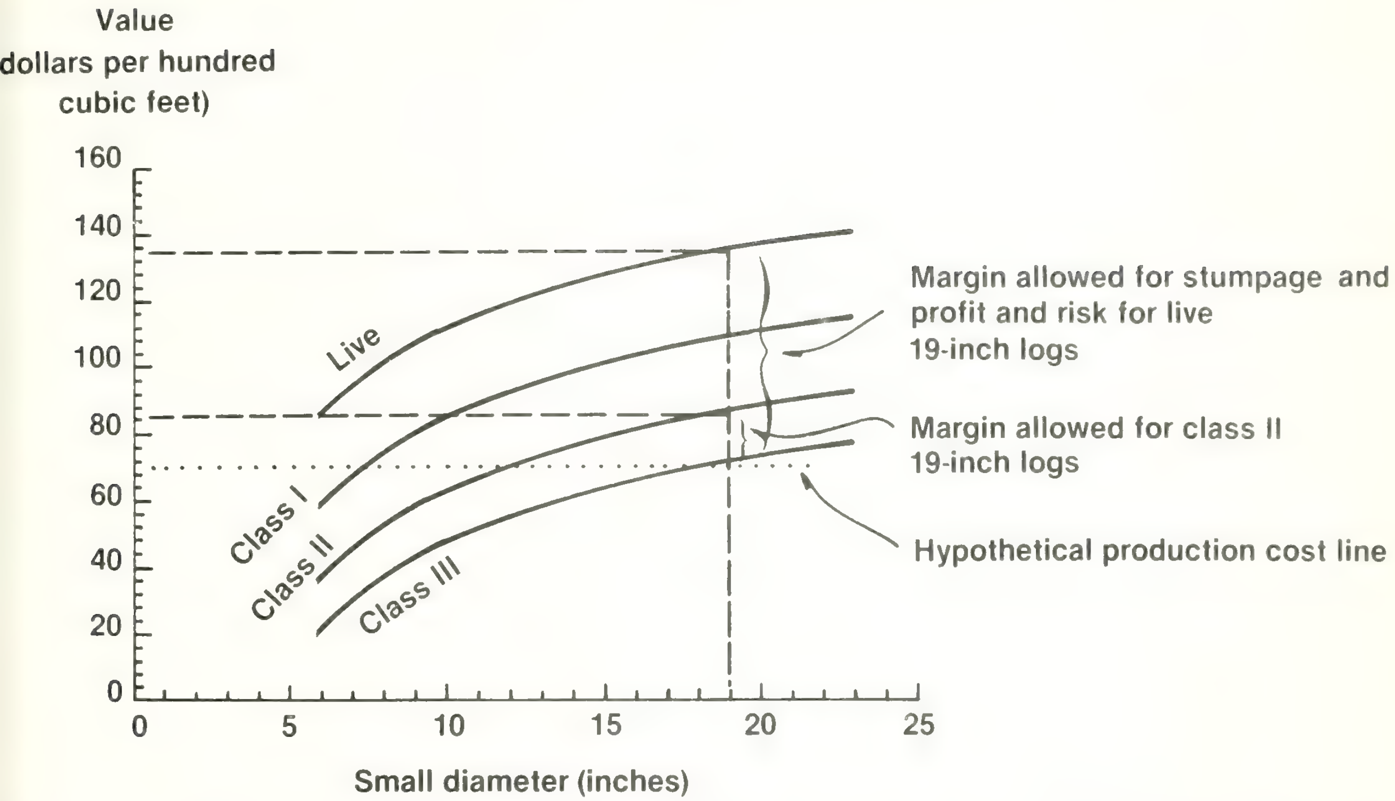
$\hat{y}(\text{live})=112.06+2.47(D)-442.65(1/D)+327.7(1/D^2)$,

$\hat{y}(\text{class I})=86.85+2.47(D)-442.65(1/D)+327.7(1/D^2)$,

$\hat{y}(\text{class II})=64.78+2.47(D)-442.65(1/D)+327.7(1/D^2)$, and

$\hat{y}(\text{class III})=51.83+2.47(D)-442.65(1/D)+327.7(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but indivudual class intercepts are, respectively, 25.10 and 0.587.



igure 12.--Values per hundred cubic feet of gross log volume by diameter and deteriora-ion class, western white pine. Includes hypothetical production cost line. These urves are the same as figure 11A curves for lumber plus chip values.

Table 9 shows values retained for logs with and without chip values by gross and net cubic scaling systems. Table 9 indicates that expressing values on a net cubic scale basis reduces the difference between classes. For example, there is a 64-percent difference (100-36) between live and class III logs based on gross cubic scale, whereas there is a 58-percent difference between the same classes based on net cubic scale. Using lumber plus chip values, rather than lumber value alone, further reduces the difference between classes. Lumber plus chip values based on net cubic scale showed a 49-percent difference. Differences between classes are reduced with net scale because defective portions of logs that will not yield solid wood products are recognized and deducted.

Table 9--Values retained expressed as a percent of live log value, western white pine[1]

Deterioration class	Lumber values		Lumber plus chip values	
	Gross cubic scale	Net cubic scale	Gross cubic scale	Net cubic scale
	Percent			
Live	100	100	100	100
Class I	74	76	77	79
Class II	51	54	57	61
Class III	36	42	44	51

---

[1] Values used to derive the percents are arithmetic averages adjusted to a common diameter. The values are dollars per hundred cubic feet of gross and net cubic scale.

nother way of looking at loss in total alue is to apportion it to volume and rade losses. Table 10 shows the average alues of logs expressed in $/CCF of gross og input. It also shows the dollar loss y class and percent loss to volume and rade.

nitially there is a large loss in lumber rade. About two-thirds of the loss in lass I and II logs was due to grade. olume losses became more important in the lder dead material because there is less rade to lose in this category.

able 10--Average log value by deterioration class and value lost by volume and umber grade, western white pine

eterioration class	Average log value[1]	Total dollar loss[2]	Loss of log value by:[3]			
			Volume		Grade	
	- - - - $CCF[4]	- - - -	$CCF[4]	Percent	$CCF[4]	Percent
ive	103.45	0	0	0	0	0
lass I	76.12	27.33	8.07	29.5	19.26	70.5
lass II	53.54	50.91	19.03	37.4	31.88	62.6
lass III	37.47	65.98	30.62	46.4	35.36	53.6

/Value is shown as arithmetic averages adjusted to a common diameter between classes.

/Live logs are the base.

/Volume loss is represented by cubic recovery percent based on gross cubic scale; value oss is represented by the average value of lumber.

/$/CCF is dollars per hundred cubic feet of gross log scale.

Tree Information

Even though most financial transactions in the forest products industry are carried out in log units, information on trees also serves an important function. For the land manager, the tree is the basic unit for inventorying lands, cruising sales, and determining expected residues for fire management. The forest products industry check-cruises trees, develops logging plans, and evaluates stand components in the form of trees. As researchers, we generally start product recovery studies with trees. Sampling begins with trees, and the ultimate effect of deterioration must be explained in trees. Breakage, for instance, is best described in trees.

Tree volumes can be separated into individual components pertaining to their utilization. These volumes expressed as percent of tree volume to a 6-inch top ar shown in table 11.

Volumes of long butts, breaks after felli and missing pieces occur on an irregular basis between classes; volumes of long bu and of missing pieces should occur on an irregular basis, but we expected breaks after felling to increase with time since death. This did not happen, but the volumes involved were so small that the results do not necessarily indicate what would happen with a larger sample. Volumes of saw logs showed the pattern we expected through class II. Class III volumes showed a slight increase, but thi was due to the random pattern in volumes of long butts, breaks after felling, and missing pieces.

The top volumes (the volume of the tree from height at 6 inches to total height) are not shown in table 11 but were a constant 2 percent between classes when expressed as a percent of total tree volume.

Deterioration after a tree's death result in three losses: (1) logging and handlin losses in the woods and mill yard, (2) losses of lumber volume, and (3) lumber degrade.

With the exception of logging and handlin losses, all other effects of deterioratio have been discussed in terms of logs. This section is directed toward presentin results, rather than interpreting the dat since the data were interpreted in the lo section. This section primarily addresse logging and handling losses, losses of lumber volume, and average losses of lumber value ($/MLT), which ultimately lead to total dollar loss for the tree.

Table 11--Individual components of volume expressed as a percent of total cubic volume to a 6-inch top, western white pine trees[1]

Deterioration class	Volume to 6-inch top[2]	Saw log	Long butt	Felling breaks	Breaks after felling	Missing pieces	No recovery	Total
	Cubic feet	- - - - - - - - - - - -	- - -	-Percent[3]-	- - - - -	- - - - -	- - - - -	- - -
Live	2,217	88.4	6.5	3.5	0	1.0	0.6	100
Class I	6,759	86.5	5.1	4.3	0.3	2.5	1.3	100
Class II	4,901	80.9	7.4	6.8	.9	1.9	2.1	100
Class III	7,720	81.2	6.5	7.6	.3	1.6	2.8	100

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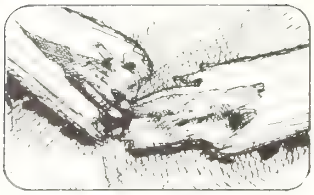
[1] Saw-log is the log portion of the tree from which some lumber was recovered. Long butt is the portion of the tree bucked at the time of felling and left onsite because of defect. Felling breaks is the portion of the tree identified as breakage caused by the felling operation. Breaks after felling is the portion of the tree identified as breakage subsequent to felling and prior to sawing. Missing pieces is the portion of the tree not accounted for. No recovery is the log portion of the tree that was sawn but from which no lumber was recovered.

[2] Calculated from the stump height to a 6-inch top. Smalian's formula used for all portions of tree other than butt log. Bruce's equation for cubic volume applied to butt logs.

[3] Weighted average of each deterioration class.



LOGGING AND HANDLING LOSSES

A summary of logging and handling losses expressed as a percentage of the tree volume to a 6-inch top is shown below:

Deterioration class	Breakage
	(Percent)
Live	3.5
I	4.6
II	7.7
III	7.9

This tabulation shows the combined effect of all breakage from table 11.

All losses of tree volume are based on the cubic-foot volume of the tree to a 6-inch top. The losses resulted from felling breaks and breaks after felling. Felling breaks accounted for the majority of the volume loss in all classes. Other breakage was caused by skidding, handling in the woods and the mill yard, and handling at the debarker. This breakage accounted for less than 1 percent of the total in each class. Breakage increased from live through the classes, but the increase was minimal between class II and III. This is a logical pattern in that wood becomes more brash as it dries. At a point somewhere between class II and III. the stem of the tree has probably reached equilibrium moisture content;[12] thus breakage does not change substantially.

The percentages for breakage shown here d not necessarily indicate breakage that would occur in other situations. The trend of increased breakage is more important than the specific rates. Breakage from felling will vary with height of tree, percentage of tree in crown, steepness and ruggedness of terrain, basal area per acre, logging method, and inherent defect. Breakage after felling will vary according to all these factors plus type of logging and debarking equipment. In this study terrain varied from moderately steep to flat. Logs were skidded by rubber-tired skidder and crawler tractor.

This increased breakage presents problems beyond the loss of volume. Virtually all mills have preferred lengths of logs for handling and processing. In this study, the preferred length for short logs was 16 feet plus trim (roughly 17 feet). The following tabulation shows the percentage of log volume that was in 16-foot lengths

Deterioration class	Percent of log volu in 16-foot lengths
Live	80.1
I	74.3
II	71.2
III	73.3

The trends in percent of volume in 16-foo lengths is emphasized rather than actual differences between classes. The trend shows the same pattern as breakage, in that live trees produced the highest percentage of volume in 16-foot lengths (80.1 percent). The percent decreased, a was expected, in class I and class II. Even though the percent of volume in 16-foot logs increased from class II (71.2 percent) to class III (73.3 percent), this is consistent with breakage shown in the previous tabulation. The reason for this apparent anomaly relates to the dead trees reaching equilibrium moisture content somewhere between class II and class III.

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[12] Equilibrium moisture content is the moisture content at which wood neither gains nor loses moisture when surrounded by air at a given relative humidity and temperature.

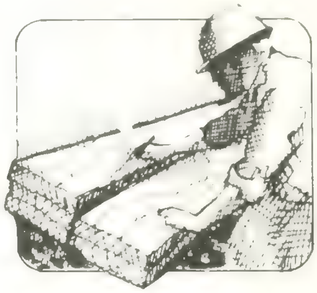
n a mill that produces items of random engths, the percent of volume in ff-length logs may not be a severe roblem; however, in a mill where pecified lengths are required, such as a tud mill, additional losses of volume ccur, and this could have a major impact n production costs as well as values btained.

RODUCT RECOVERY

roduct recovery in trees is represented y cubic recovery percent. It is the same s cubic recovery of logs but is expressed s a percent of tree volume to a 6-inch op. Average cubic recovery based on ross log scale for live logs, and classes , II, and III were 42.5, 39.7, 34.7, and 0.2 percent, respectively.[13] Appendix II, tables 24-28, presents a detailed reakdown of lumber yields by tree iameter, deterioration class, and scaling ystem.

igure 13 presents the relationship of ubic recovery to tree d.b.h. As with the ubic recovery percent curves for logs, here were highly significant differences etween class intercepts and no ignificant difference between slopes. he curve for tree cubic recovery is the ame basic shape as for logs but more radual. This is primarily due to the veraging effect of small logs on large rees. As with logs, the difference is educed between classes when net cubic ecovery percent is used.

Variables included in tree volumes but not included in log volumes include volumes lost to breakage, missing pieces, and long butts. Except for these additional variables, explanation of lumber volume loss in trees is the same as for logs.



LUMBER GRADE YIELDS

The lumber grade yields from trees is identical to yields from logs, and there is no need to duplicate the data. Figure 10 shows these lumber grade yields.

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[13] Average as used here is an arithmetic average adjusted to equalize diameter ifferences between classes.

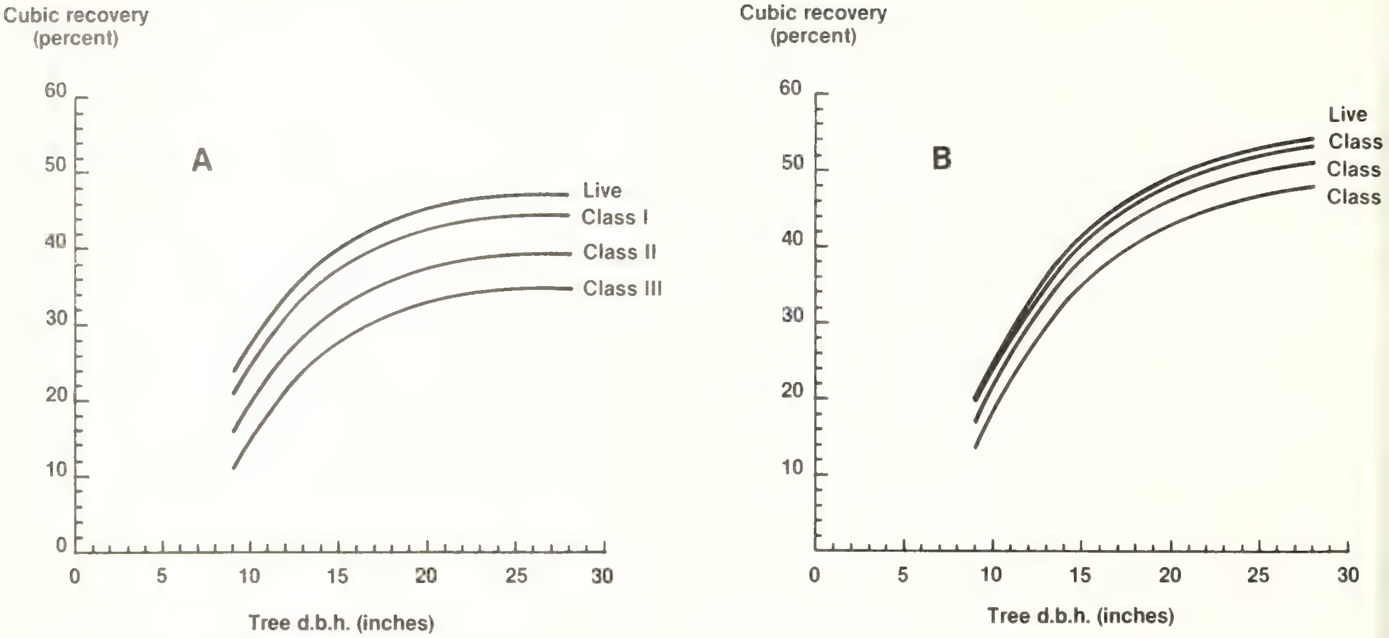


Figure 13.--Percent of cubic tree volume produced as rough green lumber by tree d.b.h. and deterioration class, western white pine:

A, gross volume; statistical information--

$\hat{y}(\text{live})=100.24-0.9540(D)-804.29(1/D)+1701.7(1/D^2)$,

$\hat{y}(\text{class I})=97.47-0.9540(D)-804.29(1/D)+1701.7(1/D^2)$,

$\hat{y}(\text{class II})=92.46-0.9540(D)-804.29(1/D)+1701.7(1/D^2)$, and

$\hat{y}(\text{class III})=87.94-0.9540(D)-804.29(1/D)+1701.7(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 8.03 and 0.503.

B, net volume; statistical information--

$\hat{y}(\text{live})=111.32-0.8473(D)-1021.44(1/D)+2376.1(1/D^2)$,

$\hat{y}(\text{class I})=110.47-0.8473(D)-1021.44(1/D)+2376.1(1/D^2)$,

$\hat{y}(\text{class II})=108.32-0.8473(D)-1021.44(1/D)+2376.1(1/D^2)$, and

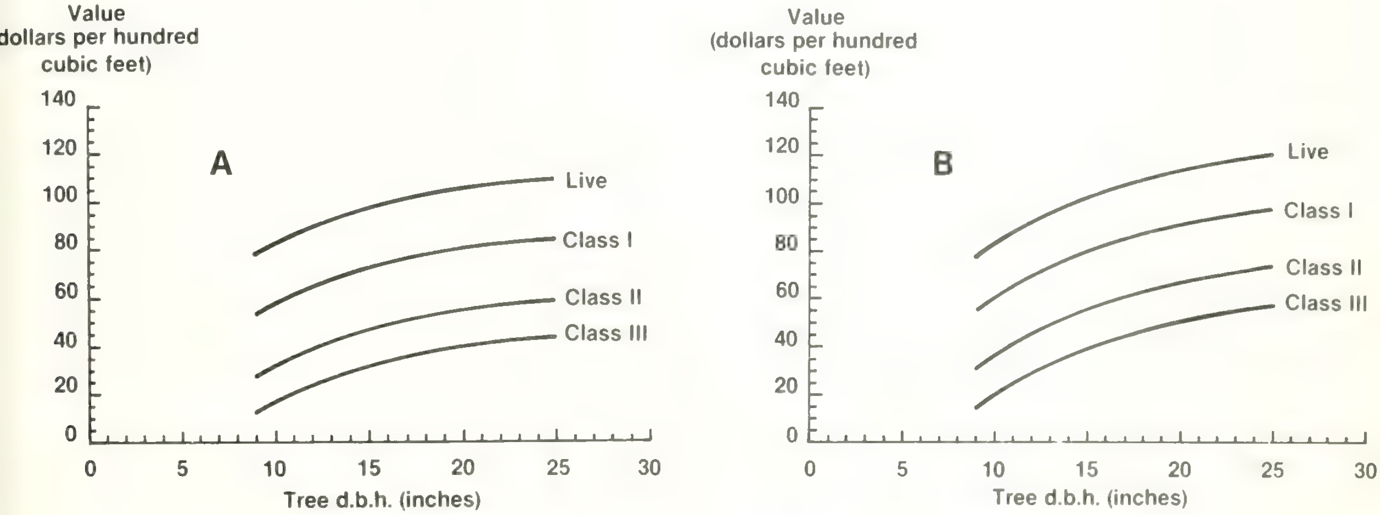
$\hat{y}(\text{class III})=105.08-0.8473(D)-1021.44(1/D)+2376.1(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 8.56 and 0.563.

OTAL DOLLAR LOSSES

osses from deterioration after death of rees can be grouped into three ategories: (1) Less log volume was elivered and sawn at the sawmill because f breakage; (2) less lumber was recovered rom an equivalent volume of dead logs awn; and (3) the lumber recovered from he dead logs was of lower quality. The total dollar loss in trees is a combination of these losses. The only difference between log value loss and tree value loss is the added effect of breakage in felling and handling.

The most functional form of expressing values is in terms of dollars per hundred cubic feet of tree input. This can be expressed as $/CCF of gross or net volume. Figure 14 shows the relationship of $/CCF to tree d.b.h. based on gross and net cubic scales.



igure 14.--Lumber values per hundred cubic feet of tree volume by tree d.b.h. and eterioration class, western white pine:

, gross volume; statistical information--

$(\text{live})=138.98-0.2147(D)-657.70(1/D)+1124.2(1/D^2)$,

$(\text{class I})=114.33-0.2147(D)-657.70(1/D)+1124.2(1/D^2)$,

$(\text{class II})=88.84-0.2147(D)-657.70(1/D)+1124.2(1/D^2)$, and

$(\text{class III})=73.46-0.2147(D)-657.70(1/D)+1124.2(1/D^2)$.

he standard error of estimate and coefficient of deter-
ination (R^2) of the set of curves possessing common
egression coefficients but individual class intercepts
re, respectively, 16.57 and 0.684.

B, net volume; statistical information--

$\hat{y}(\text{live})135.71+0.4290(D)-669.12(1/D)+973.69(1/D^2)$,

$\hat{y}(\text{class I})=112.97+0.4290(D)-669.12(1/D)+973.69(1/D^2)$,

$\hat{y}(\text{class II})=89.04+0.4290(D)-669.12(1/D)+973.69(1/D^2)$, and

$\hat{y}(\text{class III})=73.02+0.4290(D)-669.12(1/D)+973.69(1/D^2)$.

The standard error of estimate and coefficient of determination (R^2) of the set of curves possessing common regression coefficients but individual class intercepts are, respectively, 16.17 and 0.718.

Analytical Procedures

The data already presented are based on several choices that we made. This section describes how these choices were made. We will cover: (1) the method for choosing curve forms and the resulting curves, (2) derivation of the deterioration classes, and (3) statistical analysis of the various measurement (scaling) systems used in determining volumes from logs and trees.

Model Selection (Curve Form)

This is a documentation of our research experience on types of curves used in representing product recovery for predic ing either volume or value. It is not a comprehensive analysis to determine the best possible curve form.

Much information on product recovery (La et al. 1973, Henley and Plank 1974, Snellgrove et al. 1975) has been present in the general equation form of:

Straight line: $\hat{y} = b_0+b_1x_i$;

Quadratic: $\hat{y} = b_0+b_1x;+b_2x_i^2$;

Cubic : $\hat{y} = b_0+b_1x_i+b_2x_i^2+b_3x_i^3$;

where b_0 is $\hat{y}$ intercept constant;

$b_1 \ldots b_3$ are regression coefficients; and

x_i is log diameter.

The dependent variable $\hat{y}$ is product recovery volume expressed as cubic recovery percent or lumber recovery factor, and the independent variable x i log or tree diameter. The dependent variable also may be log or tree values expressed as dollars per thousand board feet of lumber tally ($/MLT), dollars pe thousand board feet of net log scale ($/MNLS), or dollars per hundred cubic feet of log input ($/CCF).

our analysis, we tested the general uations and also used inverse lynomials of the general form:

$$= b_0+b_1x_i.$$

$$= b_0+b_1x_i+b_2/x_i.$$

$$= b_0+b_1x_i+b_2/x_i+b_3/x_i^2.$$

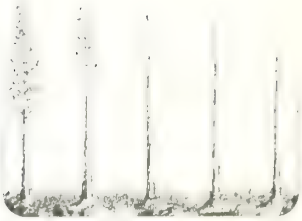
uce (1970b) and Fahey (1974) first esented these curve forms for use in oduct recovery. Woodfin and Snellgrove 976) also used these curve forms for edicting chip recovery.

this study, we found that the following neral equation consistently performed st in producing the largest R^2 values d smallest standard errors of the timate:

$$= b_0+b_1x_i+b_2/x_i+b_3/x_i^2.$$

addition to the statistical validation, is a very rational curve form. The verse polynomial curve is more respon- ve; i.e., has more curvature in lower ameters and approaches an asymptote presented by the linear form $_0+b_1x_i$) in the larger diameters. e curve is most flexible where the lationships change most rapidly. Since ny product recovery studies initiate mpling in trees, a disproportionate mber of small logs are generated--each ee, regardless of its size, produces all logs. Curve forms in the inverse lynomial group allow flexibility in ese small diameters and, on the other nd, prevent one or two observations in e larger diameters from drastically tering the shape of the curve.

Deterioration Classes



"Sample Selection" in appendix 1 details the sampling procedure. It also presents the data stratified by diameter and deterioration class. Briefly, the sample was selected on the basis of deterioration class and diameter. These deterioration classes were based on physical appearance of the trees; i.e., bark retention, needle retention, etc. Subsequent to our sample selection, the trees were scrutinized by other researchers and placed into one of seven mortality classes.[14]

Having the data based on both physical condition of the tree (deterioration classes) and time since death (mortality classes) allowed us to analyze two methods of stratifying dead timber. There are at least two reasons for analyzing the data on the basis of these different systems: (1) It has never been established whether product recovery from dead timber is best related to tree appearance or to time since death; (2) ease of application varies with type of mortality--endemic or epidemic. The first concern implies that, depending on local environmental conditions (e.g., an exposed ridgetop versus a moist bottom site), tree appearance may be a better predictor of product recovery than time since death.

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[14] Research personnel from Potlatch Corporation attempted to date mortality of the sample trees by entomological techniques.

An example could be two trees both killed at the same time, one on a ridge and the other in a protected bottom. Deterioration in the form of drying and checking may be evidenced in the physical appearance of the tree on the exposed site but not in the tree in the protected area. A system relating to time since death would imply the same rate of deterioration in both trees.

The second reason for analyzing deterioration class versus mortality class relates to application; with endemic mortality, it is easier to apply a system based on physical appearance of a tree rather than attempt to date mortality of each tree. The endemic nature of mortality in western white pine suggests physical appearance (deterioration classes) would be better for application. In epidemics where entire stands of timber are killed at the same time and date of mortality is known, it might be easier to use a system based on time since death.

ANALYSIS OF CLASSES

Even after the decision has been made to use deterioration classes, the number of classes must still be decided. Concerns about accuracy and application problems will influence the number of classes used. A system that balances ease of application with accurate predictions and separation between classes is desirable.

The timber cruiser is interested in a system that is easy to apply. Both seller and buyer of dead material are interested in a system that adequately reflects the value of dead timber and can be applied consistently.

The trees were sampled initially on the basis of five deterioration classes plus live control sample. Is this the optimu system balancing refined accuracy with ease of application? A system using fou deterioration classes would be easier to apply, but what impact would this have o accuracy? What about a system that combines all classes of dead--implying that there are no differences in value o dead trees?

Covariance analysis was used to determin if there was a difference between classe and to explain what percent of the variation was explained by regression an separation into classes. As was shown i the previous section, the general model used was:

$$\hat{y} = b_0+b_1x_i+b_2/x_i+b_3/x_i^2$$

where:

$\hat{y}$ = $/CCF gross log scale,

b_0 is y intercept constant, and

b_1, b_2, and b_3 are regression coefficients;

x is the small end log diameter.

Table 12 shows the results of partitioni total sums of squares into individual components. We delineated the portion o total variation in y explained by diameter[15] and the additional variation accounted for by classes. Since diamete entered the model first, the portion of the variation explained by diameter is constant; therefore, we could evaluate t effect of classes in reducing variation.

---

[15] Diameter (D) as used here is represented by three terms: D, 1/D, and $1/D^2$.

e tested the different systems to see if nere was a significant increase in errors esulting from reducing the number of lasses.

ecause of application problems, the even-class system based on time since eath was discarded. There was little ifference in variation accounted for etween the seven-class system 50 percent), the six-class system 59 percent), and the four-class system 58 percent).

able 12 and the results of our testing esidual sums of squares indicate that the our-class system best balances refined ccuracy with practicality in applica- ion. In all systems, diameter and lasses were sufficiently important in ccounting for variation to warrant use of oth to predict value. There was a highly significant increase in error when deterioration classes were reduced from six to four as well as from four to two. But the variation accounted for changed substantially only when the four-class system was changed to the two-class system. The significant reduction in errors resulting from increasing the number of dead classes points out the importance of class distinction in obtaining accurate predictions; however, this increase in accuracy had to be balanced with ease of field application.

able 12--Coefficient of determination (R^2) for 4 evaluation systems for western nite pine logs[1]

valuation ystem	Partitions of variation accounted for (R^2) due to: Diameter[2]	Separating into classes[2]	Regressing plus separating into classes
		Percent	
classes[3]	26	34	60
classes[4]	26	33	59
classes[5]	26	32	58
classes[6]	26	14	40

Dollars per hundred cubic feet gross log scale is the dependent variable.

Assumes diameter (D) (represented by 3 terms--D, 1/D, and $1/D^2$) enters the model irst.

Based on insect dated mortality.

Based on physical appearance.

Derived from analysis of 6 classes.

Comparison of live classes with dead.

We used $/CCF gross log scale as the dependent variable to analyze the classes. As previously shown, this $/CCF is calculated from product volume recovery and product value. Consequently, we can show how regression over diameter and separation of classes affects these individual components of the total variation in $/CCF. When product volume, expressed as cubic recovery percent, is used as the dependent variable, there is a strong relationship with diameter and less difference between classes (see fig. 6). This relationship of cubic recovery percent to diameter is to be expected since product volume is directly related to log diameter. The lack of difference between classes implies that even in the older dead categories a substantial portion of the log was produced as lumber.

When average product value ($/MLT) was predicted, there was virtually no variation accounted by regressing over diameter, but a substantial difference is shown by separating into classes (see tabulation, p. 23). Classes had a strong impact on the quality of lumber produced, whereas the relationship of log diameter to lumber quality is nebulous.

Measurement (Scaling) System Evaluation

The primary purpose of a scaling or measurement system is to facilitate buyi and selling timber. Both buyer and selle are well aware of the relationship of product recovery to estimates of log volumes since dollar evaluations of timbe are heavily dependent on this relationship. There can be other important uses of a scaling system, but for our study this relationship between log or tree volume and product recovery was of primary importance.

In this study the logs were scaled by several systems: (1) gross Scribner long log, (2) net Scribner long log, (3) gross Scribner short log, (4) net Scribner shor log, (5) gross cubic long log, (6) net cubic long log, and (7) cubic product potential long log. For details on application of these scales, see the section on scaling in appendix 1.

Neither the USDA Forest Service nor industry currently contemplate further us of mill deck scales in Region 1 (Norther Region), so the mill deck (short log) scales are not included in the analysis.

ere are a number of ways to evaluate aling systems, but we used the technique regressing lumber tally over scale lume. This method has been described in unpublished report.[16] The dependent riable, lumber tally, is the same for ch regression; consequently, R^2 values n be compared directly. The system with e highest R^2 value would be the most ecise in predicting lumber tally. ecision is also shown by standard error the estimate; i.e., the lower the andard error of the estimate, the higher e precision.

gure 15 shows the scatters for data and e regression lines for the five scaling stems. The wide scatters for net ribner and cubic product potential dicate a lack of precision, rresponding to the two lowest R^2 lues and the highest standard error of e estimate. They are the least precise r predicting lumber tally. Deductions de for net Scribner scale and cubic oduct potential overestimate defect and count for the wide variability in timates of lumber tally.

There was virtually no difference in R^2 between gross Scribner and gross and net cubic scale in predicting lumber tally. Gross Scribner volumes are based on the small end of the logs, whereas gross and net cubic are based on large as well as small end diameters. In other samples of logs where taper might be more variable than the taper in this study, the gross or net cubic would probably perform better. Likewise, in samples of logs that have high defects in the form of voids, soft rots, or char, net cubic would probably perform better than either gross Scribner or gross cubic.

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[6] Thomas D. Fahey. 1977. Paper esented at the International Forest oducts Research Society annual meeting, nver, Colorado.

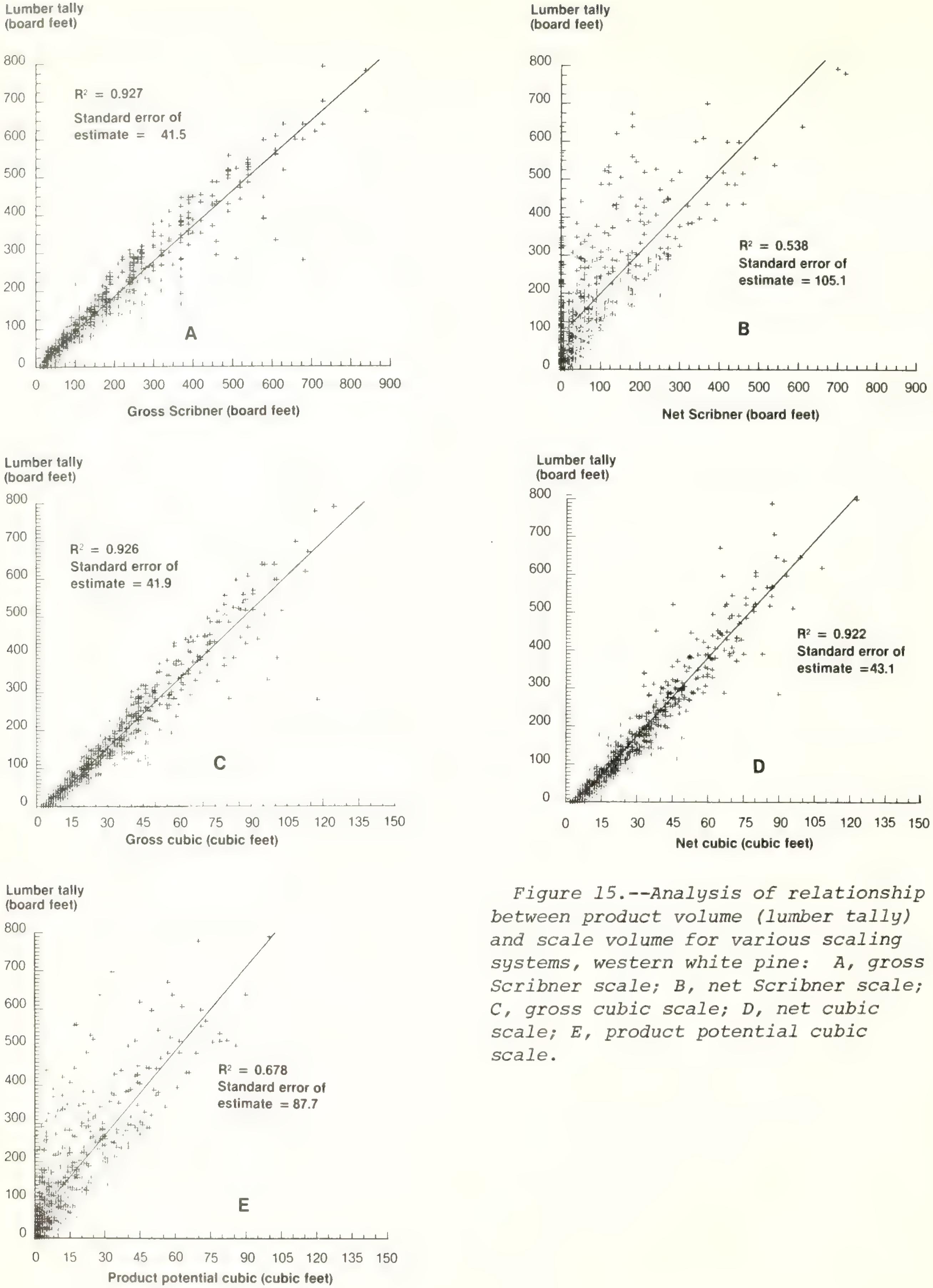

Figure 15.--Analysis of relationship between product volume (lumber tally) and scale volume for various scaling systems, western white pine: A, gross Scribner scale; B, net Scribner scale; C, gross cubic scale; D, net cubic scale; E, product potential cubic scale.

llions of board feet of western white
ne are killed annually by white pine
ister rust and the mountain pine beetle,
t less than 10 percent of this mortality
salvaged. This report provides tools
r resource managers and the forest
oducts industry to make decisions that
n increase utilization of this dead
terial. It also provides a framework
d guidelines for future research on dead
mber.

recommend a four-class system for strati-
ing live and dead timber. This includes
ree classes of dead timber ranging from
cent dead to older dead material.

og Information

velopment of defect.--When a tree dies,
undergoes a series of changes that will
fect product recovery. These changes
clude staining, heart checking
plitting), surface checking, weathering,
d a general increase in sap rots and
od borer damage. Moisture and
mperature conditions exert the greatest
ntrol on deterioration, and any
vironmental factors that control
isture or temperature will in turn
fluence deterioration. Because of the
riety of conditions that can occur on a
ngle timber sale, understanding the
sic relationship between environmental
ctors and deterioration is as important
the specific rates of deterioration
countered.

fect estimation.--Estimated defect
ries substantially, depending on the
pes of defect and the scaling system
ed for measurement. Three systems for
asuring defect were used in this study:
t Scribner, which attempts to predict
lume of lumber in board feet; net cubic,
ich attempts to predict chippable log
lume; and product potential cubic, which
tempts to predict log volume suitable
r solid wood products.

Defect percent increased as time since death increased in all three systems. Estimates were highest with net Scribner and cubic product potential as the basis for measurement; net cubic showed the lowest defect percents. Differences between net Scribner and product potential cubic were primarily due to techniques used to measure and compute defects.

Relationship of defect, scale, and product recovery.--Estimates of defect are most important in terms of product recovery, and product recovery is most meaningful when explained in terms of how the logs were measured. There should be a relationship between predicted sound log volume and actual lumber volume recovered.

Net Scribner scale and cubic product potential overestimated the impact of defects on actual volume of products; net cubic scale underestimated the impact. Volume deductions for checks in net Scribner and cubic product potential far exceed the actual lumber loss. Net cubic underestimates the impact of defects on lumber volume recovered because it is intended to predict chippable volume rather than lumber volume. The most accurate estimates of sound log volume in relationship to lumber volume was between net cubic and product potential cubic.

Product Recovery

The relationship of product volume to log volume can be expressed as recovery ratio (overrun), cubic recovery percent, or lumber recovery factor. Even though overrun based on net Scribner is the most common method of representing product recovery in the West, for our study it was the poorest system. Overrun based on net Scribner scale increased from live through the older dead classes of logs, indicating defect deductions were excessive.

Cubic recovery percent and lumber recovery factor best represent the relationship of sawn product volume to log volume. In both systems, when lumber recovery was based on either gross or net cubic scale, recovery decreased from live through the classes. In recently killed trees (class I), drying checks were the primary cause of the reduction in lumber volume. Additional losses in older dead material were due mainly to weathering, sap rots, and borers.

Chip yields are the complement to the cubic lumber recovery; i.e., smaller logs produced less lumber, thus more chips per unit of volume. Also, logs from live and recently killed trees produced more lumber and less chips, whereas older dead trees produced more chips and less lumber.

Lumber yields.--There is a substantial difference in lumber quality between live and dead timber. Live trees produce a high percentage of No. 2 Common and Better and Shop grades, whereas the older dead material produces more No. 4 and 5 Common. In the most recent dead material, lumber degrade was caused by blue stain and by splits from drying. Wormholes were present but not prevalent in the dead logs; even when present, they had a minor impact on lumber grade. Loss of lumber grade was greatest in highest quality logs because there was more grade to lose.

Lumber width decreased as time since dea increased. This reduces the value and marketability of the lumber.

Dollars per thousand board feet of lumbe tally were used to represent the average value of lumber produced. The $/MLT decreased by about 50 percent from live trees to the oldest dead class. This decrease in value is a reflection of bot lower quality lumber and narrower widths.

Log value.--Losses of log value in dead timber result from a combination of losse of lumber volume and value. Total losse are represented by dollars per hundred cubic feet of either gross or net cubic scale. The $/CCF decrease from live through the class III logs. Log value also decreases with a decrease in diameter; consequently, both size and deterioration class should be considered when values of logs are estimated. When this total loss of value was apportioned to either lumber volume or lumber value, the greatest initial loss was due to lumber value. In older dead material, th loss of lumber volume increased in importance.

Chip yields have a significant impact on the value of the marginal log; when chips can be marketed, they may mean the difference between a log's being profitable or unprofitable. Adding in th value of chips also reduces the differences between deterioration classes because some lumber recovery loss is offset by the increased production of chips.

ree Information

th the exception of logging and handling sses, all effects of deterioration can st be described in terms of logs. gging and handling losses are primarily reflection of losses from breakage. As od dries, it becomes more brash, so eakage increases with time since death. general, this breakage will decrease e volume of logs of preferred length livered to the mill. This increased rcent of off-length log volume is not as gnificant in mills processing ndom-length logs as in mills requiring ecified lengths, such as stud mills.

mber volume recovery in trees shows the me pattern as for logs; it decreases om live through the classes. The lationship of diameter to product covery in trees is important, but the eraging effect of small logs in large ees causes the curve to be more gradual.

e total dollar losses in dead trees is a mbination of the losses of lumber volume d value plus the effect of increased eakage. As with logs, the most nctional form of expressing tree values in dollars per hundred cubic feet of ee volume. The $/CCF decrease from live rough the classes and also decrease with decrease in diameter. Diameter as well deterioration class should be nsidered when log values are expressed.

Analytical Procedures

Model selection (curve form).--Six general equations were tested for predicting product recovery and product value. The general equation,

$$y=b_0+b_1x_i+b_2/x_i+b_3/x_i^2,$$

performed best, as measured by R^2 and standard error of the estimate. This inverse polynomial curve allows flexibility in small diameters. It also prevents small numbers of observations in the larger diameters from drastically altering the shape of the curve as often happens in conventional polynomial curves.

Analysis of deterioration classes.--The sample was stratified based on physical appearance of the trees (deterioration classes) and on time since death (mortality classes). Time since death was disregarded as an effective way to classify dead western white pine because of the difficulty of determining the time. Several regimes of deterioration classes were analyzed to determine the systems that best balanced ease of application with accurate predictions. A system based on one live and three dead classes of material balanced ease of application with refined accuracy. For this four-class system, the advantage from separating material into classes exceeded the advantage of regressing over diameter, when evaluated on the basis of variation accounted for.

Measurement (scaling) system evaluation.--Seven log scales were applied to the study logs. These were all variations of either Scribner or cubic scaling methods. All scales taken on the mill deck were discarded because of limited use. The other scales were evaluated on the basis of their ability to predict lumber tally volume. *Gross Scribner scale and gross cubic and net cubic scales performed about* equally well in predicting lumber tally, based on R^2 values and *standard error of the estimate. Net Scribner scale, the commonly used system of log measurement in the West, performed the poorest.* This analysis confirms that net Scribner and product potential cubic overestimated the impacts of defects for this study, whereas net cubic underestimated the impact.

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Appendix 1

Field Procedures

SAMPLE SELECTION

Selecting samples of dead timber differs from selecting live samples. Beyond the normal variation of size and quality, another variable is superimposed. Time since death becomes an important factor. The population of dead trees ranges from trees that have foliage just beginning to fade to trees that are devoid of bark and limbs.

To fulfill the objectives of our study, we used two approaches to stratifying our sample. First, we used a system that related directly to deterioration based on physical appearance of the tree; i.e., needle retention, bark retention, persistence of twigs, etc. Second, we used a system that attempted to date mortality more directly. For instance, approximate date of death was correlated with entomological characteristics--the presence of insects, insect pitch tubes, condition of pitch tubes, etc.

The study trees were selected on the Clearwater National Forest in Idaho. Individual trees were selected on the basis of d.b.h., physical appearance relating to deterioration, and stem quality. Primary emphasis for sample selection was on d.b.h. and deterioration, with an arbitrary estimate of stem quality. Efforts were taken to insure that the sample was representative of the size and quality of western white pine trees from 9- to 34-inch d.b.h. No larger trees were selected, so application of these results should be restricted to this d.b.h. range.

Deterioration was estimated in the form needle and bark characteristics. A description of the deterioration categories is as follows:

Live:	Living trees, green foliage
Class I:	Needles present, 100-percen tight bark in merchantable bole.
Class II:	Needles present, bark beginn to loosen in merchantable bo
Class III:	No needles, 90-percent and greater bark retention.
Class IV:	No needles, 25- to 89-percen bark retention.
Class V:	No needles, less than 25-percent bark retention.

Table 13 shows the distribution of sampl trees by deterioration class and diamete

Table 13--Distribution of sample trees b deterioration class, western white pine

Deterioration class	Number of trees	D.b.h. Range	D.b.h. Average[1]
		- - -Inches- -	
Live	17	10-33	22.5
Class I	32	9-28	19.5
Class II	29	13-29	21.2
Class III	43	9-34	21.2
Class IV	42	10-31	20.9
Class V	31	9-28	19.9
Total or average	194	9-34	20.8

[1] D.b.h. average is the quadratic mean.

ter the sample was selected, the date of rtality was estimated.[1] This ratification by time since death ortality codes) was only used in the mparison of mortality codes with terioration classes. We rejected use of e mortality codes because of difficulty application; consequently, no details stratification by this method are esented.

GGING, IDENTIFICATION, AND HAULING

e study trees were felled and bucked to saw logs by cooperating logging ntractors according to normal industry actice in the area. No unusual felling handling practices were used in the udy. Each log was tagged in the woods identify its origin with tree and sition in the tree. All logs were idded by tractor or rubber-tired uipment. According to normal practice, gs were bucked to "preferred lengths" r the cooperating mill when possible. this study "preferred length" was feet plus trim. The logs were hauled the mill in these lengths. Log eakage was identified and quantified in e study.

ALING

l logs delivered to the mill were scaled USDA Forest Service "check scalers." e logs were rolled out in the yard and a ng-log Scribner scale and cubic scale re taken. A mill deck short-log scale s also taken just before the logs were wed.

th Scribner scales were taken in cordance with the National Forest rvice Log Scaling Handbook of 1974.

Cubic measurements were taken in accordance with the proposed National Forest Service Cubic Scaling Handbook of June 1974. Three cubic volume estimates were taken:

1. Gross cubic scale--based on overall log dimensions.
2. Net cubic scale--based on gross cubic scale minus deductions for voids, soft rots, and charred wood. It is intended to predict the volume of a log that is suitable to produce a solid chip.
3. Product potential cubic--based on gross cubic scale minus deductions for any defects that are supposed to limit lumber tally volume. Diameters were recorded in accordance with the cubic scaling handbook, but log lengths were recorded as actual log length to the nearest one-tenth of a foot.

LUMBER MANUFACTURING

Sawing, drying, and surfacing practices of the mill were representative of general industry practice in that area. Log identity was maintained on each piece of lumber through the manufacturing process to the final point of grade tally.

Research personnel from Potlatch rporation attempted to date mortality of e sample trees.

Sawing, Drying, and Surfacing

The study logs were sawn with the objective of obtaining the highest value from each log. Logs up to and including 20 feet in length were sawn. Lumber on the green chain did not exceed 16 feet because longer items were cut into two pieces. Shop items were sawn to 5/4-inch thickness and all other items to 4/4 inch.

Production equipment in the sawmill included a double-cut band headrig, a bull edger, and a 24-foot gang trim saw.

After the logs were sawn, all study lumber was kiln dried and surfaced. Kiln schedules were adjusted to compensate for the drier lumber produced from dead trees.

Lumber Grading and Tallying

A Western Wood Products Association grading inspector either graded or supervised the grading of study lumber on the planer chain. All study lumber was graded under the Western Wood Products Association "1970 Standard Grading Rules for Western Lumber."

Each lumber item produced was placed in one of the following grades:

B and Better
 (Supreme)
C Select
 (Choice)
D Select
 (Quality)
Molding
No. 3 Clear
No. 1 Shop
No. 2 Shop
No. 1 Common (Colonial)
No. 2 Common (Sterling)
No. 3 Common (Standard)
No. 4 Common (Utility)
No. 5 Common (Industrial)

Each board was tallied by its shipping dimensions, grade, and log number.

CUBIC CALCULATIONS

Log Volumes

Cubic-foot log volumes were calculated Smalian's formula, except for butt logs.[2/] Volumes of butt logs were estimated by an equation for butt logs (Bruce 1970a).

Lumber, Sawdust, Planer Shavings, and Shrinkage

Cubic volumes of lumber were based on th size of either rough green boards or su faced dry boards. The sizes of rough g boards were determined from measurement a random sample of widths and thicknesse of boards taken as lumber was pulled fro the green chain. Three measurements were made per board--one near each end of the board and one near the middle. Sizes of surfaced dry lumber were derived by applying actual finished sizes to all th lumber tally volume.

[2/] The formula for the frustrum of a paraboloid is often referred to as Smalian's formula:

$$V = l(A_s+A_l)/2;$$

where:

V = volume in cubic units,

l = total length in linear units,

A_s = cross-sectional area in square units at small end, and

A_l = cross-sectional area in square units at large end.

oic volumes of sawdust were calculated using an average saw kerf and the nputed surface area of the rough green nber. Volumetric shrinkage and volumes planer shavings were not separated; ey were calculated by subtracting the oic volume of surfaced dry lumber from e cubic volume of rough green lumber.

ip Volumes and Weights

r general method of calculating ippable volumes and converting these lumes to weight can be shown by the llowing steps:

ross cubic log volume) - (deductions for ids, soft rots, and char) = net cubic g volume.

et cubic log volume) - (rough green nber and sawdust volumes) = estimated ippable volume.

stimated chippable volume)(density) weight of chips.

e specific method of determining weight chips follows:

Determine specific gravity for western ite pine.[3]

2. Adjust specific gravity for varying moisture content of dead trees. Moisture contents used were 92 percent for live, 32 percent for class I, 20 percent for class II, and 16 percent for class III (see footnote 3). Using specific gravity of 0.39 and these moisture contents, determine the adjusted specific gravity (Forest Products Laboratory 1974).

3. Using adjusted specific gravity, determine ovendry density by multiplying by the density of water (62.4 pounds per cubic foot). The densities were: live, 24.3 pounds per cubic foot; class I, 24.3; class II, 25.3; and class III, 25.6. Density is based on green volume and ovendry weight. Because dead material (with moisture contents below fiber saturation point) has undergone some shrinkage, densities increased in the older dead material.[4]

4. Multiply density by chippable volume to determine pounds per cubic foot for each log.

Specific gravity taken from final port of a cooperative study by Pacific rthwest Forest and Range Experiment ation and Washington State University llege of Engineering, Research Division, 75. Standing dead white pine and dead dgepole pine as raw material for mposition board. Res. Rep. 75/57-39, p., and appendixes. On file at Pacific rthwest Forest and Range Experiment ation.

[4] Fiber saturation point is defined as point at which all water is evaporated from the cell cavities but the cell walls are still fully saturated with moisture--generally about 30 percent moisture content based on ovendry weight.

Appendix 2

Table 14--Summary of log scale, lumber recovery, and cubic volumes by 1-inch diameter classes--woods-length, live western white pine logs

Log scaling diameter[1]	Number of logs	Cubic log scale[2]		Cubic defect[3]	Lumber tally volume	Lumber recovery factor[4]		Cubic volume[5]				Cubic lumber recove	
		Gross	Net			Gross	Net	Lumber	Sawdust	Chippable	Nonchippable	Gross	Ne
Inches		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		----------------Cubic feet----------------				Percent	
6	4	36.85	36.85	0	75	2.04	2.04	6.43	1.20	29.22	0	17	1
7	6	60.23	60.23	0	197	3.27	3.27	16.60	3.07	40.56	0	28	2
8	5	54.48	54.48	0	233	4.28	4.28	20.45	3.55	30.48	0	38	3
9	2	42.49	42.49	0	240	5.65	5.65	20.53	3.66	18.30	0	48	4
10	4	67.69	65.69	3.0	312	4.61	4.75	27.65	4.74	33.30	2.0	41	4
11	3	92.55	92.55	0	494	5.34	5.34	44.46	7.26	40.83	0	48	4
12	5	198.32	198.32	0	1,147	5.78	5.78	102.08	17.01	79.23	0	51	51
13	5	152.09	152.09	0	904	5.94	5.94	83.22	12.93	55.94	0	55	5
14	1	40.43	40.43	0	234	5.79	5.79	22.10	3.33	15.00	0	55	5
15	3	149.80	149.80	0	908	6.06	6.06	83.52	12.89	53.39	0	56	5
16	5	246.38	245.38	0.4	1,527	6.20	6.22	140.36	21.79	83.23	1.0	57	57
17	1	68.05	67.05	1.5	395	5.80	5.89	36.81	5.50	24.74	1.0	54	55
18	--	--	--	--	--	--	--	--	--	--	--	--	--
19	3	199.57	199.57	0	1,384	6.93	6.93	121.15	20.21	58.21	0	61	61
20	2	183.12	183.12	0	1,040	5.68	5,68	94.19	14.90	74.03	0	51	51
21	2	165.37	164.37	0.6	1,071	6.48	6.52	100.08	14.83	49.46	1.0	60	61
22	--	--	--	--	--	--	--	--	--	--	--	--	--
23	2	242.79	210.79	13.2	1,570	6.47	7.45	145.02	22.07	43.70	32.0	60	69
Total or average	53	2,000.21	1,963.21	1.8	11,731	5.86	5.98	1,064.65	168.94	729.62	37	53	54

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[1] In accordance with proposed national USDA Forest Service Cubic Scaling Handbook as of June 1974.

[2] As scaled by USDA Forest Service scalers applying the proposed USDA Forest Service Cubic Scaling Handbook rules as of June 1974; length recorde actual log length to nearest 1/10 foot.

[3] Equals (gross cubic scale - net cubic scale/gross cubic scale)(100).

[4] Gross = (lumber tally volume/gross cubic scale); net = (lumber tally volume/net cubic scale).

[5] Lumber and sawdust volumes are based on rough green dimensions. Chippable volume = (gross cubic scale - lumber, sawdust, and nonchippable cubic volume). Nonchippable volume = (gross cubic scale - net cubic scale) which is the volume of voids, soft rots, and char.

[6] Gross = (lumber cubic volume/gross log cubic volume)(100); net = (lumber cubic volume/net log cubic volume)(100).

15--Summary of log scale, lumber recovery, and cubic volume, by 1-inch diameter [illegible] length, deterioration [illegible] western white logs

ng ter[1]	Number of logs	Cubic log scale[2] Gross	Cubic log scale[2] Net	Cubic defect[3]	Lumber tally volume	Lumber recovery factor[4] Gross	Lumber recovery factor[4] Net	Cubic volume[5] Lumber	Cubic volume[5] Sawdust	Cubic volume[5] Chippable	Cubic volume[5] Nonchippable	Cubic lumber recovery[6] Gross	Cubic lumber recovery[6] Net
s		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		----------------Cubic feet----------------				Percent	
	3	16.87	16.87	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.08	[illegible]	14	14
	11	50.86	49.86	2.0	88	1.73	1.76	7.30	1.31	41.25	[illegible]	14	15
	18	182.76	180.76	1.1	638	3.49	3.53	[illegible]	9.84	117.57	[illegible]	[illegible]	[illegible]
	18	204.60	199.60	2.4	799	3.90	4.00	[illegible]	14.16	[illegible]	[illegible]	37	[illegible]
	13	167.66	166.66	0.6	725	4.32	4.35	61.21	10.98	94.47	[illegible]	[illegible]	[illegible]
	17	285.49	280.49	1.8	1,461	5.12	5.21	126.04	[illegible]	132.08	5.0	44	45
	18	332.41	330.41	0.6	1,596	4,80	4.83	137.71	24.15	168.55	2.0	41	42
	21	532.86	527.86	0.9	2,803	5.26	5.31	247.80	41.83	238.23	5.0	[illegible]	47
	18	586.47	573.47	2.2	3,300	5,63	5.75	289.04	49.34	235.09	13.0	[illegible]	50
	14	594.53	584.53	1.7	3,582	6.02	6.13	315.52	53.06	215.95	10.0	53	54
	12	546.19	521.19	4.6	3,177	5.82	6.10	281.86	46.83	192.50	25.0	[illegible]	54
	7	374.21	354.21	5.3	2,319	6.20	6.55	203.27	34.20	116.74	20.0	54	[illegible]
	8	406.91	398.91	2.0	2,420	5.95	6.07	182.72	35.42	180.77	8.0	[illegible]	46
	9	647.36	610.36	5.7	3,915	6.05	6.41	350.08	56.85	203.43	37.0	54	57
	9	623.55	575.55	7.7	3,710	5.95	6.45	325.93	54.95	194.67	48.0	52	57
	1	91.40	87.40	4.4	569	6.22	6.51	54.46	7.79	25.15	4.0	60	62
	3	290.18	253.18	12.8	1,802	6.21	7.12	158.13	26.56	68.49	37.0	54	62
or e	200	5,934.31	5,711.31	3.8	32,932	5.55	5.77	2,871.79	490.10	2,349.42	223.0	48	50

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ccordance with proposed national USDA Forest Service Cubic Scaling Handbook as of June 1974.

caled by USDA Forest Service scalers applying the proposed USDA Forest Service Cubic Scaling Handbook rules as of June 1974; length recorded as . log length to nearest 1/10 foot.

als (gross cubic scale - net cubic scale/gross cubic scale)(100).

ss = (lumber tally volume/gross cubic scale); net = (lumber tally volume/net cubic scale).

er and sawdust volumes are based on rough green dimensions. Chippable volume = (gross cubic scale - lumber, sawdust, and nonchippable cubic). Nonchippable volume = (gross cubic scale - net cubic scale) which is the volume of voids, soft rots, and char.

ss = (lumber cubic volume/gross log cubic volume)(100); net = (lumber cubic volume/net log cubic volume)(100).

Table 16--Summary of log scale, lumber recovery, and cubic volumes by 1-inch diameter classes--woods-length, deterioration class II western wh pine logs

Log scaling diameter[1]	Number of logs	Cubic log scale[2]		Cubic defect[3]	Lumber tally volume	Lumber recovery factor[4]		Cubic volume[5]				Cubic lumber recov	
		Gross	Net			Gross	Net	Lumber	Sawdust	Chippable	Nonchippable	Gross	N
Inches		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		----------------Cubic feet----------------				Percent	
5	2	14.70	14.70	0	0	0	0	0	0	14.70	0	0	
6	6	48.26	48.26	0	117	2.42	2.42	9.91	1.81	36.54	0	20	2
7	8	62.66	62.66	0	122	1.95	1.95	10.21	1.86	50.59	0	16	1
8	13	168.13	168.13	0	665	3.96	3.96	56.39	10.16	101.58	0	34	34
9	8	96.06	92.06	4.2	377	3.92	4.10	32.13	5.82	54.11	4.0	33	35
10	14	198.36	197.36	.5	874	4.41	4.43	74.57	13.36	109.43	1.0	38	38
11	9	220.75	217.75	1.4	1,123	5.09	5.16	96.81	16.91	104.03	3.0	44	44
12	14	368.16	359.16	2.4	1,625	4.41	4.52	142.24	24.42	192.50	9.0	39	40
13	5	126.71	115.71	8.7	651	5.14	5.63	55.93	9.91	49.87	11.0	44	48
14	14	506.76	471.76	6.9	2,887	5.70	6.12	251.66	43.42	176.68	35.0	50	53
15	9	298.16	287.16	3.7	1,616	5.42	5.63	141.50	24.27	121.39	11.0	47	49
16	5	139.70	126.70	9.3	700	5.01	5.52	61.66	10.37	54.67	13.0	44	49
17	8	505.33	442.33	12.5	3,138	6.21	7.09	271.36	46.65	124.32	63.0	54	61
18	4	215.59	188.59	12.5	1,108	5.14	5.88	96.98	16.42	75.19	27.0	45	51
19	4	341.36	267.36	21.7	2,039	5.97	7.63	180.03	30.13	57.20	74.0	53	67
20	4	299.71	263.71	12.0	1,711	5.71	6.49	149.38	25.41	88.92	36.0	50	57
21	1	36.32	27.32	24.8	218	6.00	7.98	18.89	3.25	5.18	9.0	52	69
22	1	101.15	83.15	17.8	389	3.84	4.68	34.71	5.66	42.78	18.0	34	42
23	3	323.26	255.26	21.0	1,927	5.96	7.55	169.72	28.52	57.02	68.0	52	66
Total or average	132	4,071.13	3,689.13	9.4	21,287	5.23	5.77	1,854.08	318.35	1,516.70	382.0	46	50

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[1] In accordance with proposed national USDA Forest Service Cubic Scaling Handbook as of June 1974.

[2] As scaled by USDA Forest Service scalers applying the proposed USDA Forest Service Cubic Scaling Handbook rules as of June 1974; length record actual log length to nearest 1/10 foot.

[3] Equals (gross cubic scale - net cubic scale/gross cubic scale)(100).

[4] Gross = (lumber tally volume/gross cubic scale); net = (lumber tally volume/net cubic scale).

[5] Lumber and sawdust volumes are based on rough green dimensions. Chippable volume = (gross cubic scale - lumber, sawdust, and nonchippable cubi volume). Nonchippable volume = (gross cubic scale - net cubic scale) which is the volume of voids, soft rots, and char.

[6] Gross = (lumber cubic volume/gross log cubic volume)(100); net = (lumber cubic volume/net log cubic volume)(100).

17--Summary of log scale, lumber recovery, and cubic volumes by 1-inch diameter classes--woods-length, deterioration class III western white logs

g er1/	Number of logs	Cubic log scale2/		Cubic defect3/	Lumber tally volume	Lumber recovery factor4/		Cubic volume5/				Cubic lumber recovery6/	
		Gross	Net			Gross	Net	Lumber	Sawdust	Chippable	Nonchippable	Gross	Net
s		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		----------------Cubic feet----------------				Percent	
	2	10.95	10.95	0	16	1.46	1.46	1.28	.25	9.42	[illegible]	12	12
	14	89.30	84.30	5.6	130	1.46	1.54	10.92	2.01	71.37	5.0	12	13
	14	152.34	145.34	4.6	463	3.04	3.19	39.33	6.87	99.14	7.0	26	27
	20	224.12	218.12	2.7	592	2.64	2.71	49.86	9.33	158.93	6.0	22	23
	18	274.58	254.58	7.3	977	3.56	3.84	83.12	15.14	156.32	20.0	30	33
	16	285.72	266.72	6.6	1,052	3.68	3.94	89.35	15.99	161.38	19.0	31	34
	19	452.96	420.96	7.1	1,623	3.58	3.86	138.77	25.12	257.07	32.0	31	33
	18	413.71	372.71	9.9	1,580	3.82	4.24	136.62	23.70	212.39	41.0	33	37
	23	702.56	614.56	12.5	3,269	4.65	5.32	282.60	49.86	282.10	88.0	40	46
	11	413.09	332.09	19.6	2,061	4.99	6.21	179.23	29.15	123.71	81.0	43	54
	15	711.50	594.50	16.4	3,368	4.73	5.66	289.82	52.02	252.66	117.0	41	49
	6	342.86	274.86	19.8	1,589	4.63	5.78	136.40	24.12	114.34	68.0	40	50
	13	693.22	601.22	13.3	3,813	5.50	6.34	329.82	57.45	213.95	92.0	48	55
	7	384.08	305.08	20.6	1,723	4.49	5.65	148.04	26.10	130.94	79.0	38	48
	2	92.79	82.79	10.8	383	4.13	4.63	33.08	5.78	43.93	10.0	36	40
	8	633.63	477.63	24.6	3,324	5.25	6.96	286.44	50.17	141.02	156.0	45	60
	4	300.95	242.95	19.3	1,559	5.18	6.42	134.76	23.50	84.69	58.0	45	55
	2	212.98	178.98	16.0	918	4.31	5.13	79.24	13.85	85.89	34.0	37	44
	2	160.11	133.11	16.9	1,050	6.56	7.89	90.55	15.74	26.82	27.0	56	68
or e	214	6,551.45	5,611.45	14.3	29,490	4.50	5.26	2,539.23	445.15	2,626.07	940.0	39	45

ccordance with proposed national USDA Forest Service Cubic Scaling Handbook as of June 1974.

scaled by USDA Forest Service scalers applying the proposed USDA Forest Service Cubic Scaling Handbook rules as of June 1974; length recorded as l log length to nearest 1/10 foot.

als (gross cubic scale - net cubic scale/gross cubic scale)(100).

ss = (lumber tally volume/gross cubic scale); net = (lumber tally volume/net cubic scale).

er and sawdust volumes are based on rough green dimensions. Chippable volume = (gross cubic scale - lumber, sawdust, and nonchippable cubic e). Nonchippable volume = (gross cubic scale - net cubic scale) which is the volume of voids, soft rots, and char.

ss = (lumber cubic volume/gross log cubic volume)(100); net = (lumber cubic volume/net log cubic volume)(100).

Table 18--Summary of log scale, lumber recovery, and cubic volumes by 1-inch diameter classes--all woods-length western white pine logs

Log scaling diameter[1]	Number of logs	Cubic log scale[2]		Cubic defect[3]	Lumber tally volume	Lumber recovery factor[4]		Cubic volume[5]				Cubic lumber recc
		Gross	Net			Gross	Net	Lumber	Sawdust	Chippable	Nonchippable	Gross
Inches		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		----------------Cubic feet----------------				Percen
5	7	42.52	42.52	0	44	1.03	1.03	3.61	.71	38.20	0	8
6	35	225.27	219.27	2.7	410	1.82	1.87	34.56	6.33	178.38	6.0	15
7	46	457.99	448.99	2.0	1,420	3.10	3.16	119.49	21.64	307.86	9.0	26
8	56	651.33	640.33	1.7	2,289	3.51	3.57	201.74	37.20	401.39	11.0	31
9	41	580.79	555.79	4.3	2,319	3.99	4.17	196.99	35.60	323.20	25.0	34
10	51	837.26	810.26	3.2	3,699	4.42	4.56	317.61	56.46	436.19	27.0	38
11	49	1,098.67	1,061.67	3.4	4,836	4.40	4.56	417.75	73.44	570.48	37.0	38
12	58	1,513.05	1,458.05	3.6	7,155	4.73	4.91	628.74	106.96	722.35	55.0	42
13	51	1,567.83	1,455.83	7.1	8,124	5.18	5.58	710.79	122.04	623.00	112.0	45
14	40	1,554.81	1,428.81	8.1	8,764	5.64	6.13	768.51	128.96	531.34	126.0	49
15	39	1,705.65	1,552.65	9.0	9,069	5.32	5.84	796.70	130.01	619.94	153.0	47
16	23	1,103.15	1,001.15	9.2	6,135	5.56	6.13	541.69	90.48	368.98	102.0	49
17	30	1,673.51	1,509.51	9.8	9,766	5.84	6.47	820.71	145.02	543.78	164.0	49
18	20	1,247.03	1,104.03	11.5	6,746	5.41	6.11	595.10	99.37	409.56	143.0	48
19	18	1,257.27	1,125.27	10.5	7,516	5.98	6.68	660.19	111.07	354.01	132.0	52
20	15	1,207.86	1,011.86	16.2	6,644	5.50	6.57	584.47	98.27	329.12	196.0	48
21	10	792.82	687.82	13.2	4,650	5.86	6.76	411.86	68.14	207.82	105.0	52
22	3	314.13	262.13	16.6	1,307	4.16	4.99	113.95	19.51	128.67	52.0	36
23	7	726.16	599.16	17.5	4,547	6.26	7.59	405.29	66.33	127.54	127.0	56
Total or average	599	18,557.10	16,975.10	8.5	95,440	5.14	5.62	8,329.75	1,423.54	7,221.81	1,582.0	45

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[1] In accordance with proposed national USDA Forest Service Cubic Scaling Handbook as of June 1974.

[2] As scaled by USDA Forest Service scalers applying the proposed USDA Forest Service Cubic Scaling Handbook rules as of June 1974; length reco actual log length to nearest 1/10 foot.

[3] Equals (gross cubic scale - net cubic scale/gross cubic scale)(100).

[4] Gross = (lumber tally volume/gross cubic scale); net = (lumber tally volume/net cubic scale).

[5] Lumber and sawdust volumes are based on rough green dimensions. Chippable volume = (gross cubic scale - lumber, sawdust, and nonchippable c volume). Nonchippable volume = (gross cubic scale - net cubic scale) which is the volume of voids, soft rots, and char.

[6] Gross = (lumber cubic volume/gross log cubic volume)(100); net = (lumber cubic volume/net log cubic volume)(100).

Table 19--Total lumber production by dimension and grade--live western white pine logs

Lumber dimension	C Select	D Select	3 Clear	1 Shop	2 Shop	3 Shop	1 Common	2 Common	3 Common	4 Common	5 Common
Inches	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -	- - - - - -	Percent - - - -	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -
1x4	0.36	0.84	0	0	0	0	0.42	0.78	3.38	1.47	0.25
1x6	.12	.55	.14	1.47	.12	0	.13	1.99	4.21	1.50	.09
1x8	.10	.14	.09	.31	.58	0	.07	1.02	5.07	1.96	.07
1x10	.06	0	.22	.95	.34	0	.07	2.94	7.54	1.59	0
1x12	.14	0	1.02	1.16	.77	0	.24	5.71	17.30	4.28	.38
5/4x4	0	.04	0	0	0	0	0	.04	.03	.05	0
5/4x6	0	.30	0	0	.22	0	0	1.14	.50	.08	0
5/4x8	.10	.41	0	.11	.34	.61	0	2.94	1.85	.15	0
5/4x10	.14	.35	0	.52	.45	.14	0	3.45	3.09	.23	0
5/4x12	0	0	0	.66	.13	0	0	5.64	4.17	.15	0
Total	1.02	2.63	1.47	5.17	2.95	.75	.92	25.67	47.16	11.48	.78

20--Total lumber production by dimension and grade--deterioration class I western white pine logs

r sion	C Select	D Select	3 Clear	1 Shop	2 Shop	3 Shop	1 Common	2 Common	3 Common	4 Common	5 Common	Total
s						Percent						
	0.05	0.46	0	0	0	0	0.21	0.50	3.53	2.65	0.30	7.70
	.05	.22	0	.13	.12	0	.12	1.72	7.96	[illegible]	.36	14.57
	.04	.15	.02	.25	.22	0	.08	1.08	9.25	5.59	.28	16.96
	0	.07	0	.49	0	0	.22	2.17	12.84	4.63	.16	20.59
	0	0	.26	.93	.49	0	.33	3.70	17.22	6.09	.30	29.32
	0	.02	0	0	0	0	0	0	.07	.03	0	.12
	.02	.03	0	0	0	0	0	.15	.20	0	0	.40
	0	.06	0	0	.04	0	0	.71	.86	.04	0	1.71
0	0	.10	0	.10	0	.09	0	1.59	1.13	.22	0	3.24
2	0	0	0	0	.06	.17	0	2.99	1.15	.12	0	4.49
	.16	1.13	.27	1.90	.94	.26	.95	14.61	54.20	24.16	1.42	100.00

e 21--Total lumber production by dimension and grade--deterioration class II western white pine logs

er nsion	C Select	D Select	3 Clear	1 Shop	2 Shop	3 Shop	1 Common	2 Common	3 Common	4 Common	5 Common	Total
es						Percent						
	0.15	0.29	0	0	0	0	0.05	0.28	2.82	5.59	1.39	10.56
	0	.10	.03	.26	.18	0	0	.40	3.82	9.73	1.41	15.94
	.04	.08	.18	.47	.54	0	0	.20	6.15	9.55	.58	17.78
	0	.11	0	.40	.16	0	.07	.65	9.20	9.66	.66	20.91
	0	0	.08	1.61	1.19	0	.29	2.77	15.37	7.55	.62	29.48
	0	0	0	0	0	0	0	0	0	.02	0	.02
	0	0	0	0	0	0	0	0	.04	.04	0	.08
	0	0	0	0	0	0	0	.13	.36	.11	0	.60
0	0	0	0	0	.06	0	0	.42	.58	.24	0	1.30
2	0	0	0	.09	.09	.37	0	1.68	.90	.21	0	3.34
	.18	.58	.29	2.82	2.23	.37	.41	6.54	39.23	42.68	4.67	100.00

Table 22--Total lumber production by dimension and grade--deterioration class III western white pine logs

Lumber dimension	C Select	D Select	3 Clear	1 Shop	2 Shop	3 Shop	1 Common	2 Common	3 Common	4 Common	5 Common	T
Inches						Percent						
1x4	0.01	0.18	0	0	0	0	0.04	0.32	2.60	10.02	3.48	1
1x6	.03	.04	0	.05	.05	0	.09	.40	3.12	11.24	3.38	1
1x8	0	0	0	.12	.14	0	0	.10	2.44	9.39	2.36	1
1x10	0	0	0	.17	.06	0	0	.08	3.75	14.31	2.43	2
1x12	0	.05	0	.05	.48	0	0	.55	7.09	16.48	3.61	2
5/4x4	0	0	0	0	0	0	0	0	.03	.06	0	
5/4x6	0	0	0	0	0	0	0	.01	0	.05	0	
5/4x8	0	0	0	0	0	.04	0	.04	0	.10	0	
5/4x10	0	0	0	0	0	0	0	.08	.22	.10	0	
5/4x12	0	0	0	0	0	.07	0	0	.20	.27	0	
Total	.04	.27	0	.39	.73	.11	.14	1.58	19.46	62.03	15.26	10

Table 23--Total lumber production by dimension and grade--all deterioration classes, western white pine logs

Lumber dimension	C Select	D Select	3 Clear	1 Shop	2 Shop	3 Shop	1 Common	2 Common	3 Common	4 Common	5 Common	Tot
Inches						Percent						
1x4	0.10	0.38	0	0	0	0	0.15	0.43	3.07	5.44	1.52	11
1x6	.04	.18	.02	.30	.11	0	.09	1.05	5.08	7.48	1.50	15
1x8	.03	.09	.06	.26	.31	0	.04	.57	5.94	7.20	.97	15
1x10	.01	.05	.03	.43	.10	0	.10	1.28	8.57	8.37	.95	19
1x12	.02	.01	.23	.84	.68	0	.21	2.77	13.69	9.40	1.41	29
5/4x4	0	.01	0	0	0	0	0	.01	.04	.04	0	
5/4x6	.01	.05	0	0	.03		0	.20	.14	.03	0	.
5/4x8	.01	.07	0	.01	.06	.09	0	.65	.60	.09	0	1.
5/4x10	.02	.08	0	.10	.07	.05	0	1.09	.97	.19	0	2.
5/4x12	0	0	0	.10	.06	.16	0	2.10	1.17	.19	0	3.
Total	.23	.92	.34	2.04	1.41	.30	.57	10.14	39.31	38.44	6.30	100.

le 24--Summary of log scale, lumber recovery, and cubic volumes by 1-inch diameter classes--live western white pine trees

h.	Number of trees	Cubic volume[1]		Cubic defect[2]	Lumber tally volume	Lumber recovery factor[3]		Cubic volume[4]			Cubic lumber recovery[5]	
		Gross	Net			Gross	Net	Lumber	Sawdust	Residual	Gross	Net
		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		--------Cubic feet-----			----Percent----	
	1	12.80	11.80	7.8	26	2.03	2.20	2.23	.41	10.16	17	19
	1	22.46	22.46	0	87	3.87	3.87	7.96	1.29	13.21	35	35
	0	0	0	0	0	0	0	0	0	0	0	0
	1	37.73	35.73	5.3	157	4.16	4.39	13.94	2.31	21.48	37	39
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	1	66.04	58.04	12.1	211	3.20	3.64	18.71	3.17	44.16	28	32
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	1	113.20	111.20	1.8	621	5.48	5.58	57.44	8.88	46.88	51	52
	2	202.55	173.55	14.3	999	4.93	5.76	93.64	14.11	94.80	46	54
	1	119.76	106.76	10.8	555	4.63	5.20	49.93	8.13	61.70	42	47
	1	84.66	75.66	10.6	379	4.48	5.01	33.53	5.62	45.51	40	44
	3	450.66	410.66	8.9	2,330	5.17	5.67	210.29	33.66	206.71	47	51
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	1	198.97	196.97	1.0	1,104	5.55	5.60	101.17	15.87	81.93	51	51
	0	0	0	0	0	0	0	0	0	0	0	0
	1	211.62	196.62	7.1	1,283	6.06	6.52	117.82	18.16	75.64	56	60
	1	258.93	205.93	20.5	1,498	5.78	7.27	135.56	21.52	101.85	52	66
	0	0	0	0	0	0	0	0	0	0	0	0
	1	202.10	168.10	16.8	824	4.08	4.90	73.20	12.01	116.89	36	44
	0	0	0	0	0	0	0	0	0	0	0	0
	1	264.42	262.42	.8	1,657	6.27	6.31	149.23	23.80	91.39	56	57
l or rage	17	2,245.90	2,035.90	9.4	11,731	5.22	5.76	1,064.65	168.94	1,012.31	47	52

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ross volume is the total cubic volume of the tree from the stump to a 6-inch top; cubic volume was derived by Smalian's formula for all ponents except butt logs, which were calculated by Bruce's (1970a) formula. Net volume is equal to gross volume minus the net cubic ect estimate of each sawlog.

quals (gross cubic scale - net cubic scale/gross cubic scale)(100).

ross = (lumber tally volume/gross cubic scale); net = (lumber tally volume/net cubic scale).

umber and sawdust volumes are based on rough green dimensions. Residual volume is equal to gross cubic volume of tree minus lumber and dust volumes.

ross = (lumber cubic volume/gross tree cubic volume)(100); net = (lumber cubic volume/net tree cubic volume)(100).

Table 25--Summary of log scale, lumber recovery, and cubic volumes by 1-inch diameter classes--deterioration class I western white pine

Tree d.b.h.	Number of trees	Cubic volume[1/]		Cubic defect[2/]	Lumber tally volume	Lumber recovery factor[3/]		Cubic volume[4/]			Cubic lumber rec	
		Gross	Net			Gross	Net	Lumber	Sawdust	Residual	Gross	Net
		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		--------Cubic feet-------			----Percent-	
9	[illegible]	22.67	21.67	4.4	48	2.12	2.22	4.05	0.73	17.89	18	1
10	0	0	0	0	0	0	0	0	0	0	0	
11	1	27.85	27.85	0	107	3.84	3.84	9.70	1.57	16.58	35	3
12	0	0	0	0	0	0	0	0	0	0	0	
13	[illegible]	152.62	135.62	11.1	682	4.47	5.03	56.78	10.27	85.57	37	4
14	[illegible]	91.46	84.46	7.7	409	4.47	4.84	35.41	6.21	49.84	39	4
15	3	173.47	152.47	12.1	612	3.53	4.01	52.87	9.13	111.47	30	3
16	[illegible]	127.30	101.30	20.4	410	3.22	4.05	36.27	6.26	84.77	28	3
17	8	628.12	542.12	13.7	2,702	4.30	4.98	242.49	42.49	343.14	39	4
18	[illegible]	256.0[illegible]	224.0[illegible]	12.5	1,191	4.65	5.32	103.98	17.85	134.19	41	4
19	5	464.41	413.41	11.0	2,160	4.66	5.22	190.94	32.10	241.37	41	4
20	3	292.81	263.81	9.9	1,447	4.94	5.48	128.39	21.43	142.99	44	49
21	6	660.86	591.86	10.4	3,422	5.18	5.78	300.82	50.54	309.50	46	51
22	[illegible]	726.97	680.97	6.3	3,848	5.29	5.65	343.27	56.45	327.25	47	50
23	4	595.17	498.17	16.3	3,062	5.14	6.15	237.61	45.32	312.24	40	48
24	5	742.39	691.39	6.9	4,148	5.59	6.00	364.12	61.69	316.58	49	53
25	0	0	0	0	0	0	0	0	0	0	0	0
26	1	220.80	160.80	27.2	938	4.24	5.83	81.50	14.13	125.17	37	51
27	4	756.25	632.25	16.4	3,766	4.98	5.96	330.34	55.76	370.15	44	52
28	1	169.78	143.78	15.3	832	7.90	5.78	73.06	12.25	84.47	43	51
29	3	646.12	521.12	19.4	3,148	4.87	6.04	280.19	45.92	320.01	43	54
Total or average	61	6,755.07	5,887.07	12.8	32,932	4.88	5.59	2,871.79	490.10	3,393.18	43	49

[1/] Gross volume is the total cubic volume of the tree from the stump to a 6-inch top; cubic volume was derived by Smalian's formula for al components except butt logs, which were calculated by Bruce's (1970a) formula. Net volume is equal to gross volume minus the net cubic defect estimate of each sawlog.

[2/] Equals (gross cubic scale - net cubic scale/gross cubic scale)(100).

[3/] Gross = (lumber tally volume/gross cubic scale); net = (lumber tally volume/net cubic scale).

[4/] Lumber and sawdust volumes are based on rough green dimensions. Residual volume is equal to gross cubic volume of tree minus lumber ar sawdust volumes.

[5/] Gross = (lumber cubic volume/gross tree cubic volume)(100); net = (lumber cubic volume/net tree cubic volume)(100).

26--Summary of log scale, lumber recovery, and cubic volumes by 1-inch diameter classes--deterioration class II western white pine trees

.	Number of trees	Cubic volume[1]		Cubic defect[2]	Lumber tally volume	Lumber recovery factor[3]		Cubic volume[4]			Cubic lumber recovery[5]	
		Gross	Net			Gross	Net	Lumber	Sawdust	Residual	Gross	Net
		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		--------Cubic feet-------			----Percent----	
	1	12.24	11.24	8.2	22	1.80	1.96	1.89	0.37	9.98	15	17
	1	20.68	20.68	0	64	3.09	3.09	5.42	1.02	14.24	26	26
	1	22.85	22.85	0	51	2.23	2.23	4.22	.76	17.87	18	18
	2	70.25	67.25	4.3	261	3.72	3.88	22.36	4.05	43.84	32	33
	1	31.97	30.97	3.1	133	4.16	4.29	11.41	2.05	18.51	36	37
	3	136.04	84.04	38.2	294	2.16	3.50	24.92	4.57	106.55	18	30
	2	116.01	99.01	14.6	409	3.52	4.13	35.00	6.28	74.73	30	35
	1	70.30	55.30	21.3	326	4.64	5.90	28.21	4.99	37.10	40	51
	4	286.27	247.27	13.6	1,177	4.11	4.76	100.84	17.79	167.64	35	41
	2	179.35	153.35	14.5	710	3.96	4.63	61.93	10.60	106.82	34	40
	2	182.24	150.24	17.6	838	4.60	5.58	72.16	12.78	97.30	40	48
	2	190.27	157.27	17.3	800	4.20	5.09	69.05	11.97	109.25	36	44
	2	181.56	153.56	15.4	753	4.15	4.90	66.61	11.05	103.90	37	43
	1	103.41	70.41	31.9	341	3.30	4.84	30.07	5.12	68.22	29	43
	2	245.30	211.30	13.9	1,356	5.53	6.42	117.74	20.36	107.20	48	56
	4	550.26	448.26	18.5	[illegible]	5.02	6.16	240.15	41.05	269.06	44	54
	1	175.07	147.07	16.0	804	4.59	5.47	70.18	11.96	92.93	40	48
	4	620.34	448.34	27.7	2,714	4.38	6.05	238.18	40.44	341.72	38	53
	2	384.02	314.02	18.2	2,109	5.49	6.72	181.93	31.67	170.42	47	58
	2	545.25	425.25	22.0	2,782	5.10	6.54	245.28	41.26	258.71	45	58
	1	177.36	125.36	29.3	452	2.55	3.61	39.96	6.65	130.75	[illegible]	32
	0	0	0	0	0	0	0	0	0	0	0	0
	1	285.17	201.17	29.5	1,087	3.81	5.40	95.10	16.05	174.02	[illegible]	47
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	1	306.74	212.74	30.6	1,044	3.40	4.91	91.47	15.51	199.76	[illegible]	43
or ge	43	4,892.95	3,856.95	21.2	[illegible]	4.35	5.52	1,854.08	318.35	2,720.52	38	48

ss volume is the total cubic volume of the tree from the stump to a 6-inch top; cubic volume was derived by Smalian's formula for all
nents except butt logs, which were calculated by Bruce's (1970a) formula. Net volume is equal to gross volume minus the net cubic
t estimate of each sawlog.

als (gross cubic scale - net cubic scale/gross cubic scale)(100).

ss = (lumber tally volume/gross cubic scale); net = (lumber tally volume net cubic scale).

ber and sawdust volumes are based on rough green dimensions. Residual volume is equal to gross cubic volume of tree minus lumber and
st volumes.

ss = (lumber cubic volume/gross tree cubic volume)(100); net = (lumber cubic volume/net tree cubic volume)(100).

Table 27--Summary of log scale, lumber recovery, and cubic volumes by 1-inch diameter classes--deterioration class III western white pine trees

Tree d.b.h.	Number of trees	Cubic volume[1]		Cubic defect[2]	Lumber tally volume	Lumber recovery factor[3]		Cubic volume[4]			Cubic lumber re	
		Gross	Net			Gross	Net	Lumber	Sawdust	Residual	Gross	Ne
		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		--------Cubic feet-------			----Percent	
9	2	23.45	19.45	17.1	36	1.54	1.85	2.87	0.56	20.02	12	1
10	2	42.66	37.66	11.7	128	3.00	3.40	10.76	1.86	30.04	25	2
11	3	66.92	52.92	20.9	126	1.88	2.38	10.64	1.92	54.36	16	2
12	2	70.46	56.46	19.9	198	2.81	3.51	16.67	3.08	50.71	24	3
13	4	145.35	138.35	4.8	489	3.36	3.53	41.65	7.64	96.06	29	3
14	0	0	0	0	0	0	0	0	0	0	0	0
15	4	189.38	161.38	14.8	435	2.30	2.70	37.08	6.76	145.54	20	23
16	5	326.09	277.09	15.0	1,275	3.91	4.60	109.65	19.45	196.99	34	40
17	4	272.96	218.96	19.8	943	3.45	4.31	81.21	14.45	177.30	30	37
18	4	338.16	276.16	18.3	1,319	3.90	4.78	113.82	20.25	204.09	34	41
19	5	432.84	287.84	33.5	1,350	3.12	4.69	116.07	20.68	296.09	27	40
20	7	716.05	509.05	28.9	2,739	3.82	5.38	235.45	41.61	438.99	33	46
21	3	341.39	306.39	10.2	1,660	4.86	5.42	142.66	25.21	173.52	42	47
22	2	236.97	204.97	13.5	869	3.67	4.24	75.53	12.87	148.57	32	37
23	7	908.81	635.81	30.0	3,448	3.79	5.42	296.61	52.33	559.87	33	47
24	1	128.18	107.18	16.4	491	3.83	4.58	42.29	7.25	78.64	33	39
25	3	509.01	398.01	21.8	2,060	4.05	5.18	178.17	31.19	299.65	35	45
26	4	681.92	461.92	32.3	2,232	3.27	4.83	192.39	34.67	454.86	28	42
27	4	823.40	601.40	27.0	3,193	3.88	5.31	275.40	48.32	499.68	33	46
28	3	636.96	455.96	28.4	2,803	4.40	6.15	240.81	42.41	353.74	38	53
29	2	445.07	332.07	25.4	2,297	5.16	6.92	198.96	32.42	213.69	45	60
30	0	0	0	0	0	0	0	0	0	0	0	0
31	2	453.66	322.66	28.9	1,399	3.08	4.34	120.54	21.22	311.90	27	37
Total or average	73	7,789.69	5,861.69	24.8	29,490	3.79	5.03	2,539.23	446.15	4,804.31	33	43

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[1] Gross volume is the total cubic volume of the tree from the stump to a 6-inch top; cubic volume was derived by Smalian's formula for a components except butt logs, which were calculated by Bruce's (1970a) formula. Net volume is equal to gross volume minus the net cubic defect estimate of each sawlog.

[2] Equals (gross cubic scale - net cubic scale/gross cubic scale)(100).

[3] Gross = (lumber tally volume/gross cubic scale); net = (lumber tally volume/net cubic scale).

[4] Lumber and sawdust volumes are based on rough green dimensions. Residual volume is equal to gross cubic volume of tree minus lumber a sawdust volumes.

[5] Gross = (lumber cubic volume/gross tree cubic volume)(100); net = (lumber cubic volume/net tree cubic volume)(100).

e 28--Summary of log scale, lumber recovery, and cubic volumes by 1-inch classes--all deterioration classes, western white pine trees

h.	Number of trees	Cubic volume[1/] Gross	Cubic volume[1/] Net	Cubic defect[2/]	Lumber tally volume	Lumber recovery factor[3/] Gross	Lumber recovery factor[3/] Net	Cubic volume[4/] Lumber	Cubic volume[4/] Sawdust	Cubic volume[4/] Residual	Cubic lumber recovery[5/] Gross	Cubic lumber recovery[5/] Net
		--Cubic feet--		Percent	Board feet	Board feet per cubic foot		--------Cubic feet-------			----Percent----	
	5	58.36	52.36	10.3	106	1.82	2.02	8.81	1.66	47.89	15	17
	4	76.14	70.14	7.9	218	2.86	3.11	18.41	3.29	54.44	24	26
	6	140.08	126.08	10.0	371	2.65	2.94	32.52	5.54	102.02	23	26
	4	140.71	123.71	12.1	459	3.26	3.71	39.03	7.13	94.55	28	32
	10	367.67	340.67	7.3	1,461	3.97	4.29	123.78	22.27	221.62	34	36
	5	227.50	168.50	25.9	703	3.09	4.17	60.33	10.78	156.39	27	36
	9	478.86	412.86	13.8	1,456	3.04	3.53	124.95	22.17	331.74	26	30
	9	589.73	491.73	16.6	2,222	3.77	4.52	192.84	33.87	363.02	33	39
	16	1,187.35	1,008.35	15.1	4,822	4.06	4.78	424.54	74.73	688.08	36	42
	9	773.53	653.53	15.5	3,220	4.16	4.93	279.73	48.70	445.10	36	43
	13	1,192.69	962.69	19.3	4,969	4.17	5.16	436.61	74.44	681.64	37	45
	14	1,401.68	1,103.68	21.3	5,985	4.27	5.42	526.53	89.12	786.03	38	48
	11	1,303.57	1,158.57	11.1	6,390	4.90	5.52	560.02	94.93	648.62	43	48
	9	1,152.01	1,032.01	10.4	5,437	4.72	5.27	482.40	80.06	589.55	42	47
	16	2,199.94	1,755.94	20.2	10,196	4.63	5.81	862.25	151.67	1,186.02	39	49
	10	1,420.83	1,246.83	12.2	7,399	5.21	5.93	646.56	109.99	664.28	46	52
	4	684.08	545.08	20.3	2,864	4.19	5.25	248.35	43.15	392.58	36	46
	10	1,722.03	1,268.03	26.4	6,988	4.06	5.51	613.24	105.11	1,003.68	36	48
	10	1,963.67	1,547.67	21.2	9,068	4.62	5.86	787.67	135.75	1,040.25	40	51
	7	1,563.61	1,221.61	21.9	7,700	4.92	6.30	676.97	114.08	772.56	43	55
	7	1,527.48	1,184.48	22.4	7,395	4.84	6.24	654.67	106.51	766.30	43	55
	0	0	0	0	0	0	0	0	0	0	0	0
	4	940.93	691.93	26.5	3,310	3.52	4.78	288.84	49.28	602.81	31	42
	0	0	0	0	0	0	0	0	0	0	0	0
	1	264.42	262.42	.8	1,657	6.27	6.31	149.23	23.80	91.39	56	57
	1	306.74	212.74	30.6	1,044	3.40	4.91	91.47	15.51	199.76	30	43
or ge	194	21,683.61	17,641.61	18.6	95,440	4.40	5.41	8,329.75	1,423.54	11,930.32	38	47

---

ss volume is the total cubic volume of the tree from the stump to a 6-inch top; cubic volume was derived by Smalian's formula for all nents except butt logs, which were calculated by Bruce's (1970a) formula. Net volume is equal to gross volume minus the net cubic t estimate of each sawlog.

als (gross cubic scale - net cubic scale/gross cubic scale)(100).

ss = (lumber tally volume/gross cubic scale); net = (lumber tally volume/net cubic scale).

er and sawdust volumes are based on rough green dimensions. Residual volume is equal to gross cubic volume of tree minus lumber and st volumes.

ss = (lumber cubic volume/gross tree cubic volume)(100); net = (lumber cubic volume/net tree cubic volume)(100).

Snellgrove, Thomas A., and James M. Cahill.
1980. Dead western white pine: characteristics, product recovery, and problems associated with utilization. USDA For. Ser. Res. Pap. PNW-270, 63 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

When a western white pine (*Pinus monticola* Dougl. ex D. Don) tree dies, it undergoes a series of physical changes. The effects of these changes on product recovery are evaluated. Tabular information and prediction equations provide the tools necessary for using this resource.

KEYWORDS: Dead timber, lumber recovery, lumber yield, wood utilization, deterioration (wood), western white pine (dead), *Pinus monticola*.

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

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Pacific Northwest
Forest and Range
Experiment Station

Research Paper
PNW 271
June 1980

Plastic Cages To Protect Douglas-Fir Seedlings From Animal Damage in Western Oregon

Glenn L. Crouch

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lastic Cages To Protect Douglas-Fir Seedlings
rom Animal Damage in Western Oregon

eference Abstract

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80. Plastic cages to protect Douglas-
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W-271, 6 p., illus. Pacific Northwest
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YWORDS: Barriers (-animal damage
ntrol, animal damage control, seedling
rvival.

Research Summary
Research Paper PNW-271
1980

Many species of mammals damage young planted conifers in the Douglas-fir region. Foresters have tried various measures to protect trees from a variety of animals, including repellants, poisons, traps, hunting, fences, and wire cages. One area with persistent problems is west of Corvallis, Oregon, in the Alsea Ranger District of the Siuslaw National Forest. Since large-scale clearcutting was begun there about 1958, foresters have tried various fencing and caging procedures to protect trees, but most efforts were abandoned because of high costs of materials, installation, and maintenance, and questionable benefits.

In the late 1960's, an effective plastic cage was developed by the DuPont Company and the Fish and Wildlife Service, U.S. Department of the Interior. Installation of these cages was soon begun on a large scale in the Alsea District. Although many small-scale tests of the cages had been conducted by researchers, there were no adequate evaluations underway or planned in 1972 when this study was started.

The evaluations reported here were conducted to compare survival and height growth of protected and unprotected, newly planted Douglas-fir seedlings. In the study, performance of seedlings protected by two types of the plastic cages was compared with that of uncaged trees.

In the two tests, after 5 years, cagi
increased seedling survival by 0 and
percent compared with uncaged samples.
Caged trees were 0.8 and 1.2 feet tall
than their uncaged companions. In both
tests, caging was judged relatively
unimportant to establishment of the st
because survival of uncaged trees was
percent or more. Although caged trees
grew better than uncaged trees, maximu
benefits from caging were not attained
because the cages or their installati
interfered with height growth of 50
percent of the caged samples.

During the study, annual incidence of
terminal injuries to uncaged trees by
animals was moderate, averaging about
percent. A higher incidence of injury
would probably have resulted in greate
benefits from caging in both survival
growth.

troduction

y species of mammals damage young
nted conifers in the Douglas-fir region
the Pacific Northwest (Black et al.
9, Crouch 1969). Foresters have tried
ious measures, including repellants,
sons, traps, hunting, fences, and wire
es to protect trees from elk (Cervus
adensis roosevelti Merriam), black-
led deer (Odocoileus hemionus
umbianus Richardson), snowshoe hare
pus americanus Erxleben), and rabbits
lvilagus spp.), mountain beaver
lodontia rufa Rafinesque), and voles
crotus spp.). Damage by these animals
urs periodically in many parts of the
ion, but one well-known area with
sistent problems is west of Corvallis,
gon, in the northern half of the Alsea
ger District of the Siuslaw National
est. Here, foresters have planted and
lanted many clearcut blocks over the
t 20 years, but regeneration is still
r on many acres because of mortality
slowed growth. On some areas, elk,
r, hare, and mountain beaver may
age trees on the same acre. Cattle
o graze on some of these sites, but
wsing by them has not been detected.

ea foresters tried various fencing and
ing procedures to protect their trees
aly 1969), but most efforts were aban-
ed because of high costs of materials,
tallation, and maintenance, and
stionable benefits. Moreover, most
ces and wire cages had to be removed
trees enlarged, or they interfered
h growth. Removal was another costly
cedure.

the late 1960's Campbell (1969)
orted on the value of plastic caging
erial to protect trees. This product,
ar®,[1] was developed cooperatively by the DuPont Company and the Fish and Wildlife Service, U.S. Department of the Interior. After much experimentation with cage composition and structure and field tests of effectiveness, a standardized cage was developed in the early 1970's. The cages are described in detail by Campbell (1969) and Campbell and Evans (1975); in general, they are lightweight polypropylene mesh tubes. They are mass produced and are photodegradable in 3 to 5 years, which precludes the need for removal as the trees grow. The cages are costly, installation can be difficult, and there is a tendency for some tree leaders to become entangled in the mesh, resulting in deformed trees.

Foresters in the Alsea District began large-scale installation of plastic cages in 1971. Shortly thereafter, cages were placed on trees on more than 1,000 acres annually; and for a short period in the mid-1970's, 100 or more trees were caged on virtually every acre planted. During this time, various numbers of trees per acre were planted and caged throughout the District, but the kinds of protectors and method of installation were similar on all areas.

Although many small-scale tests of the cages had been conducted by researchers, there were no adequate evaluations of the operational practice underway or planned in 1972 when this study was begun. The investigation was designed to compare survival and height growth of protected and unprotected Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seedlings planted and caged by the USDA Forest Service or by contract workers. To preclude special treatment I did not select study sites until after trees had been planted and cages installed.

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culture of any product or service to the exclusion
thers which may be suitable.

Study Area and Methods

The evaluation was conducted near Harlan, Oregon, in an area under intensive forest management. Large-scale clearcutting on National Forest land was begun there about 1958. By 1965, it was apparent that animals were responsible for poor stocking and suppressed height growth of planted seedlings on many acres. A few trees that had been protected by wire cages were more than three times as tall as nearby unprotected trees.

Foresters began placing plastic protectors on trees in 1972 in the Harlan area, and seedlings planted and caged on three typical clearcut blocks were selected for study in that year (test A). In 1973, a somewhat different cage was used, but the method of installation was the same as in the previous year. Trees on three of the newly treated blocks were added to the study in 1973 (test B).

Both years, 30-inch cages of 2-inch diameter were installed. In 1972, cages were of 1/2-inch diamond mesh and designed to disintegrate in 3 or 4 years. Those applied in 1973 were of 3/8-inch mesh and somewhat more resistant to breakdown. Protectors were placed over newly planted seedlings and sandwiched between two sharpened 36-inch long laths that were driven about 6 inches into the ground. Cages and laths were then tied together near the top and midway with 1/8-inch rope.

For each test, three replications of 20 protected and 20 unprotected trees each were selected and marked on the three clearcut blocks each year. These 180 protected trees of each cage type and unprotected trees were compared. Trees were measured when they were marked and were examined in April and September for 5 succeeding years. Data from each test were analyzed separately by analysis of variance at P=0.05.

Results

Survival

Test A.--After five growing seasons, survival was not significantly differe between caged and uncaged trees (table More than 85 percent of all trees plant were alive at that time. Comparisons ar individual clearcut blocks also showed differences in survival. Most mortality of both caged and uncaged trees occurre within the first 3 years after planting Table 2 shows that caging was responsi for the loss of 4 percent of the caged trees, but this amount had little beari on the lack of advantage for caging. Animals caused 5-percent mortality of uncaged trees but killed no caged seedlings.

Table 1--Survival and heights of caged and uncaged Douglas-fir seedlings 5 yea after planting in western Oregon[1]

Test	Survival	Heig
	Percent	Fee
Test A:		
Caged seedlings	86a	3.8
Uncaged seedlings	88a	3.0
Test B:		
Caged seedlings	93a	4.5
Uncaged seedlings	80b	3.3

[1] Trees in test A were planted and caged in winter 1971-72 and those in test B i winter 1972-73. Means within tests and attributes followed by the same letter are not significantly different (P=0.05)

le 2--Mortality to Douglas-fir seedlings planted western Oregon, by cause[1]

Test	Caging procedure	Animals	Other	Total
		Percent		
t A:				
aged seedlings	4	0	10	14
ncaged seedlings	--	5	7	12
t B:				
aged seedlings	0	1	6	7
ncaged seedlings	--	5	15	20

ees in test A were planted and caged in winter 1-72 and those in test B in winter 1972-73.

st B.--Survival of caged trees was sig-
ficantly greater than that of uncaged
edlings (table 1). More than 90 percent
the caged trees were alive after
years, whereas survival of uncaged
ees averaged 80 percent. Most mortality
curred within 3 years after planting.
mortality of caged trees was attrib-
ed to caging. Animals were responsible
a 5-percent loss of uncaged trees and
percent of caged trees.

eight Growth

st A.--Caged trees were significantly
ller than uncaged trees after five
owing seasons (table 1). The difference
ounted to about 0.8 foot. Cages, or the
stallation procedure, interfered with
height growth of 55 percent of the
ged trees (table 3). Trees so affected
re no taller than uncaged trees, whereas
ose unencumbered by cages were more than
foot taller than the uncaged or entan-
ed ones. Caged trees were noticeably
ller after the 2d year; they achieved
eir maximum height advantage over the
caged trees in the 4th and 5th years.

Table 3--Interference of caging with height growth of Douglas-fir seedlings surviving for 5 years after planting in western Oregon[1]

Category	Test A	Test B
	Percent of trees	
Cause of interference:		
Tree terminal deformed in cage or grown through mesh	32a	30a
Installation of cage--supporting stakes or fastenings broken; cage and tree on ground, or cage not on tree	23b	20b
	Height of trees (feet)	
Effect of caging trees:		
No interference	4.3a	5.0a
Interference	3.3b	3.9b
Uncaged trees	3.0b	3.3c

[1] Trees in test A were planted and caged in winter 1971-72 and those in test B in winter 1972-73. Means within tests and categories followed by the same letter are not significantly different (P=0.05).

Test B.--Caged trees were 1.2 feet taller than the uncaged trees after 5 years (table 1). The cages or their supports interfered with the growth of nearly one-half the caged trees, but those affected were, nonetheless, significantly taller than the uncaged trees (table 3). Trees growing without interference were more than a foot taller than those affected by the cages or their installation. Protected trees were taller by the 2d year and showed their greatest advantage over the uncaged trees in the 5th year after planting.

Animal Damage

Mean annual incidence of animal damage to terminal shoots is shown in table 4. Although variations occurred from year to year, the mean is nearly identical in both tests.

Deer were the most frequent cause of injury, followed by elk, hare, and mountain beaver (table 5). More than 80 percent of the uncaged trees in test A and more than 90 percent of those in test B sustained damage to terminal shoots. Among caged trees, incidence of damage was 20 and 30 percent in test A and test B.

Table 4--Incidence of animal damage to terminal shoots of caged and uncaged Douglas-fir seedlings surviving for 5 years after planting in western Oregon[1]

Test	Years after planting					Annual mean
	1	2	3	4[2]	5[2]	
	Percent					
Test A:						
Caged	1	0	2	11	13	5
Uncaged	26	23	46	28	42	33
Test B:						
Caged	0	0	13	11	7	7
Uncaged	23	79	30	27	8	33

---

[1] Trees in test A were planted and caged in winter 1971-72 and those in test B in winter 1972-73.

[2] Most damage to caged trees occurred on terminals that had grown beyond the cages.

Table 5--Animals damaging terminal shoots of cage and uncaged Douglas-fir seedling surviving for 5 after planting in western Oregon[1]

Animal	Test A		Test B	
	Caged	Uncaged	Caged	Unc
	Percent[2]			
Black-tailed deer	15	66	22	
Roosevelt elk	5	11	11	
Snowshoe hare	1	11	0	
Mountain beaver	1	8	0	
All animals[3]	20	82	30	

---

[1] Trees in test A were planted and caged in winter 1971-72 and those in test B in winter 1972-73.

[2] Of trees damaged at least once.

[3] Values are not totals of damage by individual species. Some trees were damaged by more than one of animal.

iscussion

ges did not affect survival in test A t resulted in about 13 percent more live ees after 5 years in test B. Part of is gain may have resulted from selection better trees by the cage installers. r test A, we had no difficulty choosing caged trees to pair with those that re caged. For test B, the following ar, comparable uncaged seedlings were ch more difficult to find.

all blocks studied, continued high rvival of caged and uncaged trees is pected and should provide stocking that ll require precommercial thinning 10 to years after planting. Thus, on these udy areas, caging appears to have had ttle survival benefit to the future mber crop.

otection improved height growth in both sts, although results suggest that ximum benefits may have been attained the 5th year. Measurements after 6 ars on test A trees showed a smaller fference in height between caged and caged trees than was found in year 5. st injuries to caged trees occurred ter they had outgrown their cages. By e 5th year, more than 80 percent of the ged trees were taller than their cages. rhaps cages should be taller, or tensions might be added to prolong the riod of protection.

ged trees in test B grew better than ose in test A, but growth of uncaged ees was similar. Selection of better ees by the cage installers may account r part of the gain in test B.

e high incidence of cage interference sulting in substantial reduction in owth of caged trees appears to justify riodic maintenance of cages, if use of e described cages and installation ocedures are continued.

In this study, the annual incidence of terminal injury to uncaged trees by animals was moderate, averaging about 33 percent over 5 years. More important, the incidence was low in the critical 1st year after planting in both tests. Higher levels of injuries would probably have resulted in greater benefits from protection in both survival and growth.

Costs for protection of trees must be repaid as economically meaningful increases in timber production. Caging was costly and appeared to result in marginal benefits on the areas studied here. The key to successful use of this procedure is proper installation and maintenance, but only on sites where forest managers are reasonably sure that gains from protection will more than offset costs.

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Crouch, Glenn L.
1980. Plastic cages to protect Douglas-fir seedlings from animal damage in western Oregon. USDA For. Serv. Res. Pap. PNW-271, 6 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Effects of plastic mesh cages designed to protect Douglas-fir seedlings from animals were evaluated in western Oregon. In two tests over 5-year periods, caging increased survival by 0 and 13 percent and increased height growth by 0.8 and 1.2 feet compared with uncaged trees. Benefits from caging might have been greater if damage had been more prevalent during the tests.

KEYWORDS: Barriers (-animal damage control, animal damage control, seedling survival.

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Research Paper
PNW-272

June 1980

Duff Reduction by Prescribed Underburning in Douglas-fir

David Sandberg

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Author

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uff Reduction by Prescribed Underburning in Douglas-fir

ference Abstract

dberg, David V.
980. Duff reduction by prescribed underburning in Douglas-fir.
SDA For. Serv. Res. Pap. PNW-272, 18 p. Pacific Northwest Forest
nd Range Experiment Station, Portland, Oregon.

dictive equations for duff reduction and mineral soil exposure by scribed fire are presented. An explanation is suggested for the endence of duff combustion on surface fuel combustion. Surface e duration and fuel moisture estimates of the National Fire-Danger ing 1,000-hour timelag are the best predictors for reduction in st duff. Duff layers with less than 30-percent moisture burned ependently of surface fires.

words: Duff, fire effects, prescribed burning, site preparation.

esearch Summary

search Paper PNW-272

30

sumption of duff from the forest floor often the most important effect of scribed fire. The degree of air lutant emission, chemical change in the l, and site preparation are usually inated by the amount of duff consumed. this paper, measurements of duff uction are reported from a series of erburning experiments in partial cut nds of (predominately) Douglas-fir in tern Washington and Oregon. The ects of fire on duff were found to be dictable from preburn estimates of duff sture content, calculated fuel stures, and/or an inventory of fuel and f loadings. Certain published dictive schemes are verified. Finally entative theory to account for the unt of duff consumed is presented.

re is a critical moisture value, near percent, below which duff burns inde- dently of woody fuels, so nearly all f is burned. On the other hand, tually no combustion takes place in any f layer exceeding about 120-percent moisture content. Between these values, duff burns only under the influence of external heat supplied by the burning of fine surface fuel.

Duff is apparently dried out by a surface fire to a depth dependent more on the duration of fire than on the amount of fuel burned, with that depth equal (in inches) to the square root of diameter reduction (in inches) in the surface fuels.

Thousand-hour timelag fuel moisture estimates from the National Fire-Danger Rating System (NFDR-Th) are the most useful inputs for predicting duff reduction. Approximately 0.06 inches (0.14 centimeters) additional duff is consumed for each 1-percent decrease in NFDR-Th. Assuming a specific gravity of 0.165, this amounts to approximately 1 ton per acre additional duff. An average 2.5-percent additional duff is consumed, and 2.3-percent additional soil is bared by the 1-percent change. The difference between a spring and fall burn, with a typical difference of 15 to 20 percent in NFDR-Th, can result in a difference of 20 tons per acre consumed and 45-percent mineral soil exposure.

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ntroduction

onsumption of duff from the forest floor s of interest in planning or evaluating ne effects of fire. Duff combustion is ften the most important contributor to ir pollutant emissions and to chemical nanges in the soil. The amount of duff emaining after a wildfire or prescribed urn greatly affects the moisture-holding apacity and erodibility of the soil and s suitability for regeneration by atural or artificial seeding. It is ncumbent upon the forest manager to redict and manipulate the factors causing ineral soil exposure, duff retention, and uff reduction by fire.

n this paper, measurements of duff eduction are reported from a series of nderburning experiments in partial cut tands of (predominately) Douglas-fir in estern Washington and Oregon. Effects of ire on duff are found to be predictable rom preburn estimates of duff moisture ontent, components of the National ire-Danger Rating System (NFDR), and/or n inventory of fuel and duff loadings. ertain published predictive schemes are erified. Finally a tentative theory to ccount for the amount of duff consumed is resented.

everal investigators have sought to predict uff consumption, either empirically or rom an energy balance approach, from reburn environmental measurements. Those rom northern conifer forests are resented here for comparison. None have een verified locally to a degree ufficient for operational use in Douglas-ir. Studies reporting exclusively on xperience in ponderosa pine or Southern orests are not mentioned here because of ifferences in physical properties and oisture relations.

Review

Van Wagner (1972) reported on duff consumption by fire in jack pine and red and white pine stands in eastern Canada. An equation was presented to account for the weight of duff consumed, based on a balance between energy available from a surface fire and that required to preheat the duff to ignition. Duff consumption was also regressed against Duff Moisture Code, a component of the Canadian Forest Fire Weather Index approximating a moisture timelag of 1,000[1] hours (Van Wagner 1975). Mineral soil exposure was also plotted against duff moisture content, but with poor correlation. His duff consumption equation has had the widest application of those reviewed here, having been incorporated in the computer-based fire model package of the USDA Forest Service Northern Forest Fire Laboratory by Albini (1976a, b).

---

[1] The interpretation of "timelag" is different in American versus Canadian fire-danger rating systems. Duff Moisture Code, according to the Canadian interpretation, has a timelag of 288 hours. According to Van Wagner (correspondence dated October 2, 1979, on file at the Pacific Northwest Forest and Range Experiment Station, Seattle, Washington), that is approximately equivalent to a 1,000-hour timelag fuel in the American system.

Chrosciewicz (1978) also regressed duff reduction and mineral soil exposure on the Duff Moisture Code. Predictive equations are presented for use in jack pine clearcuts.

Shearer (1975) examined the effectiveness of prescribed fire for site preparation in Montana (Miller Creek) larch/spruce/fir forests. Reduction of duff varied with moisture content of the lower one-half of the duff layer. Artley et al. (1978) substantiated that result. Beaufait et al. (1977) also reported on duff consumption in Montana (Miller Creek and Newman Ridge) larch/Douglas-fir harvest units. They found duff moisture content and Buildup Index, which has an approximate 1,200-hour timelag response, to be well correlated with each other and with consumption.

Norum (1975) regressed duff consumptio and percent duff reduction on multiple preburn inventory variables in Montana (Lubrecht Experimental Forest) larch/Douglas-fir stands which had bee partial cut 50 years before. Early sea results were sufficiently different fr late season to warrant two sets of regressions. Variables found to be important included preburn loadings of duff, woody fuels, shrubs, and forbs, a well as duff moisture content and windspeed. He found that the same independent variables useful to explain duff consumption are also the best to predict woody fuel consumption, substantiating the hypothesis that duff consumption depends on the burning of woody fuels. Norum (1977) presents aid for predicting percent duff reduction based on moisture content in the lower duff, with optional input of fine (0- t 3-inch diameter) woody fuel consumption (in the range 0-20 tons per acre).

In summary, considerable evidence exist to conclude that duff moisture content, especially that in the lower one-half, the most important determinant of duff consumption. There is general agreemen that there is a critical moisture value, near 30 percent, below which duff burns independently of woody fuels, so nearly all duff is consumed. On the other han virtually no burning takes place in duf exceeding about 120-percent moisture content. Between these values, duff bur only under the influence of external hea supplied by the burning of fine surface fuel. Only minor success in predicting mineral soil exposure has been reported.

Much of the research reviewed above appears applicable to underburning in coastal Douglas-fir partial cuts. Such applicability had not been verified in controlled experiments, however.

lethods

is study of duff combustion is part of a rger effort to produce guidelines for rescribed underburning in partial cut tands dominated by Douglas-fir in western ashington and Oregon. Thirteen stands ere selected to represent the range of onditions typical of such burns. The tudy area (fig. 1) includes seven Ranger stricts in four National Forests. The eographic area over which prescribed nderburning is operational was spanned, was the range in elevation (300-1 400 eters or 1,000-4,500 feet), slopes -75 percent), fine fuel loadings .8-4.4 kilograms per square meter or 20 tons per acre), duff thicknesses nit averages of 4.7-11.2 centimeters, or 9-4.4 inches), stand densities (30-1,130 ve-inch and larger diameter trees per ctare, or 12-457 per acre), crown covers 0-100+ percent), and time of year (June October) (table 1, fig. 2).

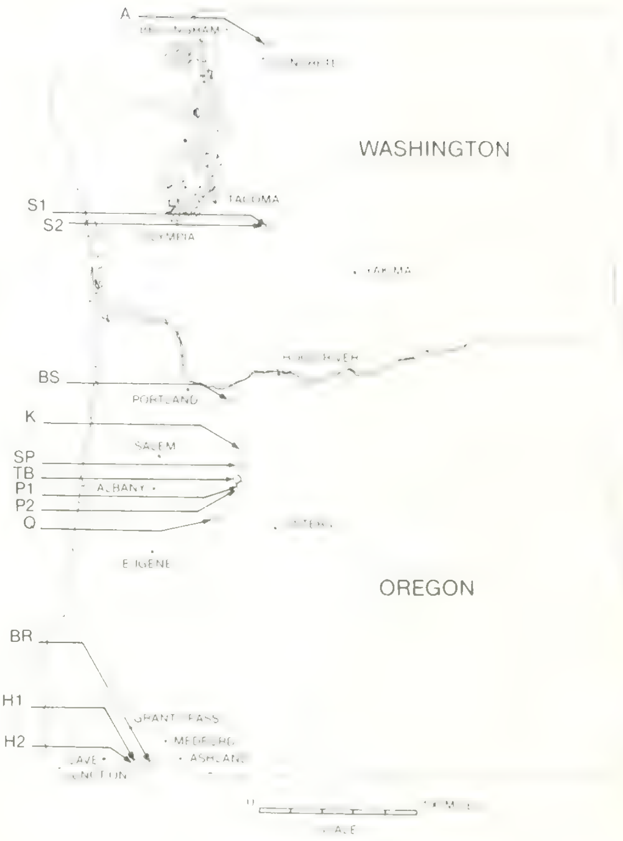

Figure 1.--Map of western Washington and Oregon showing location of prescribed underburning study units.

able 1--Characteristics of prescribed underburning study units

nit	Elev.	Slope	Aspect	Fuel load		Crown cover	Average tree diameter	Date burned
				<7.6 cm	>7.6 cm			
	Meters	Percent		kg/m^2	kg/m^2	Percent	Centimeters	
	300	45	W	2.9	9.4	71	57	6/28/78
1	700	60	NW	4.0	7.9	13	72	6/20/78
2	700	60	NW	3.1	6.7	12	65	7/12/78
S	700	35	S	2.5	15.0	56	43	6/08/78
	1 000	5	W	2.9	9.0	13	62	6/16/77
P	1 200	45	N	2.5	7.9	17	69	10/20/77
3	1 400	45	SW	1.6	12.1	31	49	6/28/78
1	700	40	NE	2.5	5.8	82	43	7/31/78
2	800	25	N	2.5	4.5	69	34	7/30/78
	1 000	50	S	1.6	10.3	32	57	6/08/78
R	1 400	45	NW	2.9	7.6	100+	25	10/14/77
1	1 100	55	N	2.2	13.0	15	38	8/31/77
2	1 000	75	N	2.5	11.0	10	52	9/17/77

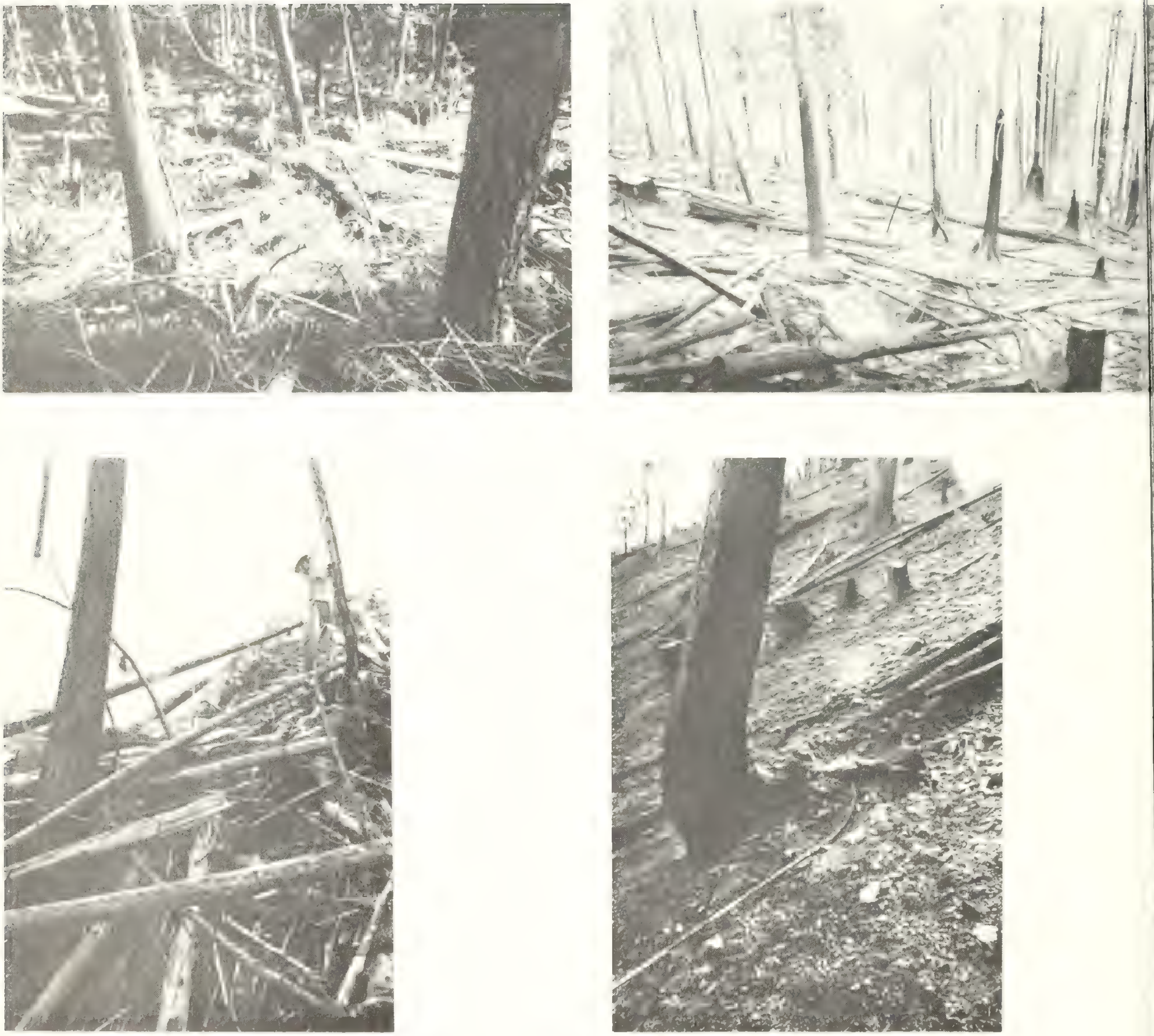

Figure 2.--Photographs of underburning study units BS (top), and H1 before and after treatment.

ffort was made to reduce variability
uded in the sampling by limiting the
ronmental conditions encountered.
er, by selecting burn sites as
erent as possible from one another, we
nded to develop predictive equations
ul in the broadest practical applica-
s. No doubt the varied and unmeasured
conditions and the differing tech-
es for applying fire were limiting
ors in the goodness-of-fit of our
ession equations. On the other hand,
eant to stretch each theoretical
tionship to its limit and provided
tions with the least potential for
se.

thickness and consumption were
ured at 192 grid points over a
ctare (2-1/2-acre) plot area within
unit burned. Spikes were driven
h with the top of the duff (F and H
rs), and the exposed length and
ance to mineral soil measured after
ing according to the method described
eaufait et al. (1977). The percent of
ral soil exposed by fire was estimated
subtracting the percentage of spikes
d in mineral soil after burning from
percent found in soil before burning.
urn mineral soil exposure averaged 3.3
ent on skyline-yarded units. Moisture
ent in both the upper and lower
half of the duff layer was sampled at
locations within the plot just prior
urning. Moisture contents are
essed as a percentage of ovendried
weight.

Fine fuel loading was measured at crossed pairs of 1-1/2-meter (4.9-foot) transect planes (Brown 1974). Fuel consumption was calculated by remeasuring fuels along each transect plane. The average reduction in fuel particle diameters for fine and coarse fuels was calculated and used to estimate flame residence time (Anderson 1969, Harmathy 1976), T_R (minutes), where

$$T_R = 3.15\Delta d,$$

and Δd is the fuel diameter reduction in centimeters. This relationship was originally derived for cases where T_R represented the burnout time for pieces completely consumed by fire. The relationship between residence time and partial diameter reduction is even more likely to be linear, but the coefficient shown may be in error. It is the best estimate available.

Standard errors were calculated for each mean fuel loading estimate on each unit. Standard errors in duff loading and reduction in duff thickness averaged less than 0.4 centimeters (0.16 inch). Estimates of percent duff reduction have a standard error of 3.7 percent. Estimates of down woody fuel loading have standard errors of less than 15 percent of their mean value. Duff moisture contents, which have typical coefficients-of-variation of about 40 percent of their mean value, have standard errors near 20 percent.

Standard fire-weather observation stations were set up on each unit, usually several weeks in advance of burning. All components of the National Fire-Danger Rating System (NFDR) were calculated (Deeming et al. 1977). NFDR components were also calculated from observations at the nearest permanent fire-weather station for comparison.

Results and Discussion

The units burned under a variety of conditions. Some barely carried fire, while others were on the verge of creating control difficulty. Strip headfires generally were used, with strip widths averaging about 7 meters (20 feet) and ranging from 2 to 20 meters (6 to 66 feet). Backing fires were occasionally used in slash concentrations (e.g., Unit A),[2] and often used where fuel moistures were especially low (H1, P2). Flame lengths ranged from 0.15 to 3.7 meters (0.5 to 12 feet) and were usually held to between 0.9 and 1.5 meters (3 and 5 feet).

Multiple linear regressions were calculated for duff depth reduction, duff thickness remaining after fire, percent duff reduction, and percent mineral soil exposure. NFDR fuel moisture estimates, measured fuel and duff moisture contents, preburn duff thickness, and woody fuel diameter reduction were used as independent variables. Each regression presented includes only those independent variables theorized to have a direct causal relationship, are readily available to the user, and are significant at the 95-percent level.

Data from all units were used in at leas one regression, but several events occurred which required exclusion of one or more units from others. For example, two units (TB, A) had duff layers in excess of 10.5 centimeters (4.1 inches. While this created no difficulty in explaining the amount (depth) of duff reduction, neither the percentage of duff removed nor the percentage of mineral so exposed nor the amount of duff remaining after fire was predictable from weath fuel moisture data without their exclusi Duff on two units (P1, H2) continued smolder for several hours after surfa fuels ceased burning. Naturally, the amount of duff consumed on those units showed no relationship to the amount surface fuels consumed. Finally, sufficient rainfall occurred during ignition on two units (TB, H2) to invalidate any regression attempting t predict percentage consumption on thos units. These anomalies helped to define the endpoints of applicability in the predictive equations that follow and resulted in a variable sample size of 9 to 13 units for regression analysis. Exclusions are noted below when regressions are presented.

In the remainder of this section, resu will be presented and discussed separa for each objective. Our understanding the thermophysical process involved wi be presented, followed by an evaluatio the degree to which the current litera explains our findings. Regression equations will then be presented and discussed. Regressions on one variable are plotted along with the 95-percent confidence interval for the regression line.

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[2] Specific units will hereinafter be referred to by using the one- or two-character code shown in figure 1.

ff Depth Reduction

f combustion usually occurs under the luence of an external heat load plied by burning woody surface fuels. is known, however, that duff will burn ependently under some conditions. eral burns in this experiment were erved to contain plots that smoldered several hours after surface fuels sed burning. Insufficient data were lected to model the event; but in all es, the moisture content of the upper f was less than 30 percent; in the er duff, less than 90 percent; and the ional Fire-Danger Rating System 00-hour timelag fuel moisture (NFDR-Th) 17 percent or less. Windspeed also an important but unmeasured influence.

f depth reduction for the 24 plots hin each unit was regressed against e fuel consumption on each plot in an ort to further describe the conditions er which duff combustion depends on face fuel combustion. A low correlation fficient would be consistent with the othesis that a duff layer was ficiently dry to burn independently of face fuels, once ignited. The variation fuel or duff moisture content within h unit is unknown other than by fficients of variation between moisture ples. Linear correlation coefficients for the five units where NFDR-Th sture content was greater than or equal 23 percent, and for the two units where n fell, range from 0.52 to 0.72, while se for units where the NFDR-Th estimate 22 percent or less range from 0.00 to 5.

It appears from these data that two moisture regimes were encountered. Under moist conditions, i.e., in all cases where NFDR-Th timelag moisture was greater than 22 percent and lower duff moisture exceeded 135 percent, or where rain fell, duff reduction is strongly dependent on fine fuel consumption. Where those indexes were dry, i.e., less than 18 and 90 percent, respectively, woody fuel consumption is not important. A transition regime exists where parts of a unit are dry and others moist, so that duff reduction is only weakly dependent on fuel consumption.

Burnout Theory.--Van Wagner (1972) provides the only algorithm available for which we collected the necessary input data. He theorized that the efficiency of heat transfer from a surface fire to the duff surface, which he called "emissivity," is variable. The approach was rendered empirical by obtaining the dependence of emissivity, e, on duff moisture content, M_D (percent), through linear regression:

$$e = 0.77 - 0.00543\ M_D. \qquad (1)$$

Combined with this expression is the duff weight consumed, W_D, obtained from an energy balance equation:

$$W_D = \frac{T_R \times 1074e}{110 + 6.2M_D}\ \text{kg/m}^2, \qquad (2)$$

where T_R (minutes) is the fire duration. Substituting equation 1 for e into equation 2 and allowing $T_R = 1$, yields the expression in common use:

$$W_D = \frac{0.941\ \ (141.8 - M_D)}{17.74 + M_D}\ \text{kg/m}^2.$$

His equation, however, is unsuitable for our use in its present form because the empirical coefficients are limited to light surface fuels (less than 0.25 kg/m^2 or 1.1 T/A).

Whereas Van Wagner's (1972) observations of duff reduction have a maximum value of 2.9 kg/m^2, our measured duff reduction ranged from 3.0 to 11.1 kg/m^2 (assuming an average specific gravity of 0.165)[3]. Van Wagner's fuels were composed of longer needles than Douglas-fir and would result in a lower bulk density. Similarly, his predictive equation is based on an assumed fire duration of 1 minute, while we estimate flame durations of 6-12 minutes. Finally, his empirical derivation of emissivity becomes unrealistically low, in fact negative, for some of our measured duff moistures.

In retrospect, it appears that had Van Wagner ignored all samples where $M_D \leq 35$ percent, an average value of e = 0.34 could have been used for the remainder of his examples. A better fit of those data would result from substituting that value of e in equation 2, such that:

$$W = \frac{58.9\ T_R}{17.74 + M_D}\ \mathrm{kg/m^2} \qquad (3)$$

avoiding the conceptual difficulty a variable emissivity presents.

A comparison of our results with predicted values from the modified form of Van Wagner's equation 3 comprises figure 3. Our calculated values of residence time were used, arbitrarily limited to a maximum of 12 minutes, i.e., considering consumption of 3.8-centimeter (1.5-inch)-diameter and smaller fuels. Duff moistures, M_D, are the average of upper and lower duff moisture contents.

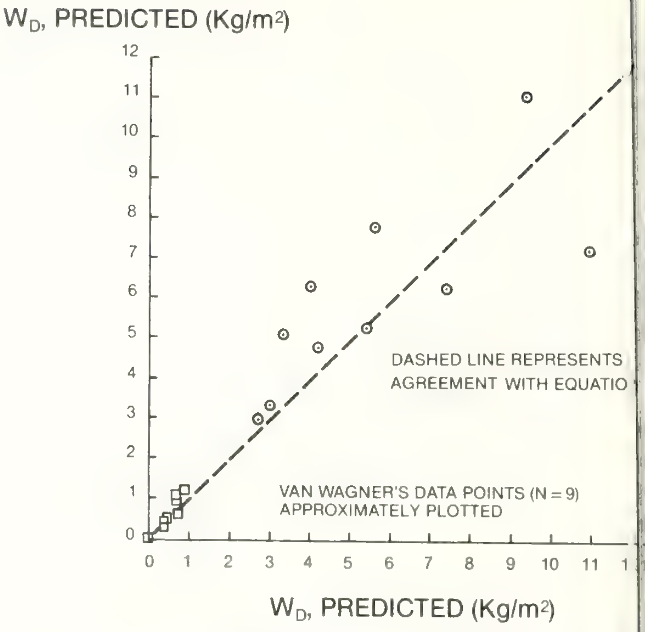

Figure 3.--Comparison of duff weight co sumption with a prediction equation (eq adapted from Van Wagner (1972). Duff moisture content exceeds 35 percent.

Three units (K, H1, SP) were excluded f the comparison because the average duff moisture content was less than 35 percent. Agreement is good, considerin that no empirical coefficients remain. Admittedly, both residence time and duf bulk density were estimated from other measurements, so that the comparison doe not have the complete credibility it mig otherwise have. The close agreement supports, but in no way proves, the theo proposed by Van Wagner, as amended. However, the plotted results appear nonlinear, suggesting yet a more complex relationship of W_D with T_R.

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[3] Ryan, K. C. Unpublished literature review dated November 18, 1977, on file with the Forest Residues Program, Pacific Northwest Forest and Range Experiment Station, Seattle, Washington.

Vagner's (1972) theory also includes ssumption that all duff consumed is ted during passage of the flaming : in surface fuels. He points out some duff is probably partially dried ne flaming front but ignites later. ne extent that the latter is true, the nt of heat absorbed by the duff layer be limited by the rate of heat usion through the layer which will be ted, but not linearly, to the duration eat supplied.

erature rise ($t_i - t_x$) at depth x timeters) within a simple conducting l when the surface temperature is enly raised to t_s (°C) is described ne equation:

$$\frac{t_x - t_s}{t_i - t_s} = \text{erf}\left(\frac{x}{2\sqrt{\alpha T}}\right), \tag{4}$$

e t_i is initial temperature, α is thermal diffusivity of the substance /s), and erf $\left(\frac{x}{2\sqrt{\alpha T}}\right)$ is Gauss' error gral (Jakob and Hawkins 1957). If we ne that t_x, t_i, and t_s are equal 00°, 20°, and 800°C, respectively, quation can be written to estimate the n of heat penetration:

$$X \cong 2.2\sqrt{\alpha T} \quad . \tag{5}$$

tions 4 and 5 are not sensitive to which must vary by about 200°C to ce a 10-percent change in x.

Thermal properties of most organic materials are similar to the properties of water, which has a thermal diffusivity of about 14×10^{-4} cm^2/s. For example, Martin (1963) showed that the diffusivity of bark is near 13×10^{-4} cm^2/s over a wide range of bark densities and moisture contents. Diffusivity in forest duff layers has been reported in the approximate range of 10 to 14×10^{-4} cm^2/s (e.g., Feddes 1973, VanWijk 1963, Baver et al. 1972). We will assume $\alpha = 14 \times 10^{-4}$ cm^2/s for the duff layers consumed, due to their high moisture content.

Finally, it is necessary to estimate the duration, T, of the external heat load supplied. Since woody fuels on the surface burn in residual flaming, then smoldering, stages long after the flaming front has passed, the heat load must exceed flame duration, i.e., $T > T_R$. Harmathy (1972, 1976) describes the residual phase, dominated by the oxidation of char, and suggests that a reasonable estimate of total fire duration is twice the flaming duration, i.e.,

$$T = 2\,T_R \cong 6.3\Delta d \text{ (minutes)},$$

where xd (centimeters) is the diameter reduction of woody fuels. When an equation is substituted in equation 5 for duff drying depth, x, duff consumption, cm_D (centimeters), results, such that:

$$X = cm_D \cong 1.6\sqrt{\Delta d} \text{ (centimeters)}; \tag{6a}$$

or with X and Δd in English units, simply:

$$X = in_D \cong \sqrt{\Delta d} \text{ (inches)}. \tag{6b}$$

Equation 6 is plotted as a solid line in figure 4. Also plotted, for comparison, are the data from this study and a dashed line representing a linear regression of cm_D on the square root of αd, such that:

$$cm_D = -0.16 + 1.59\sqrt{\Delta d} \text{ (centimeters)}, \quad (7)$$

$$(N = 11;\ r^2 = 0.71;\ s_{\hat{y}.x} = 0.48 \text{ cm}),$$

where N is the number of observations, r^2 is the coefficient of determination, and $s_{\hat{y}.x}$ is the standard error. Excluded from this analysis were two units (H2, P1) where duff burned independently for several hours after surface burning ceased.

Agreement with equation 7 is insuffici to prove the theory embodied in equati because of the limited number of obser tions and the assumed relationship of duration to the reduction in fuel diameters. There is no doubt, however, th our results are better explained by th duration of fires than by the heat loa supplied (i.e., fuel consumed) by the fires. That explanation also rectifie the knowledge that duff consumption depends on woody fuel consumption with observations that the relationship is neither linear nor direct, nor is the consumption of the two strata entirely simultaneous.

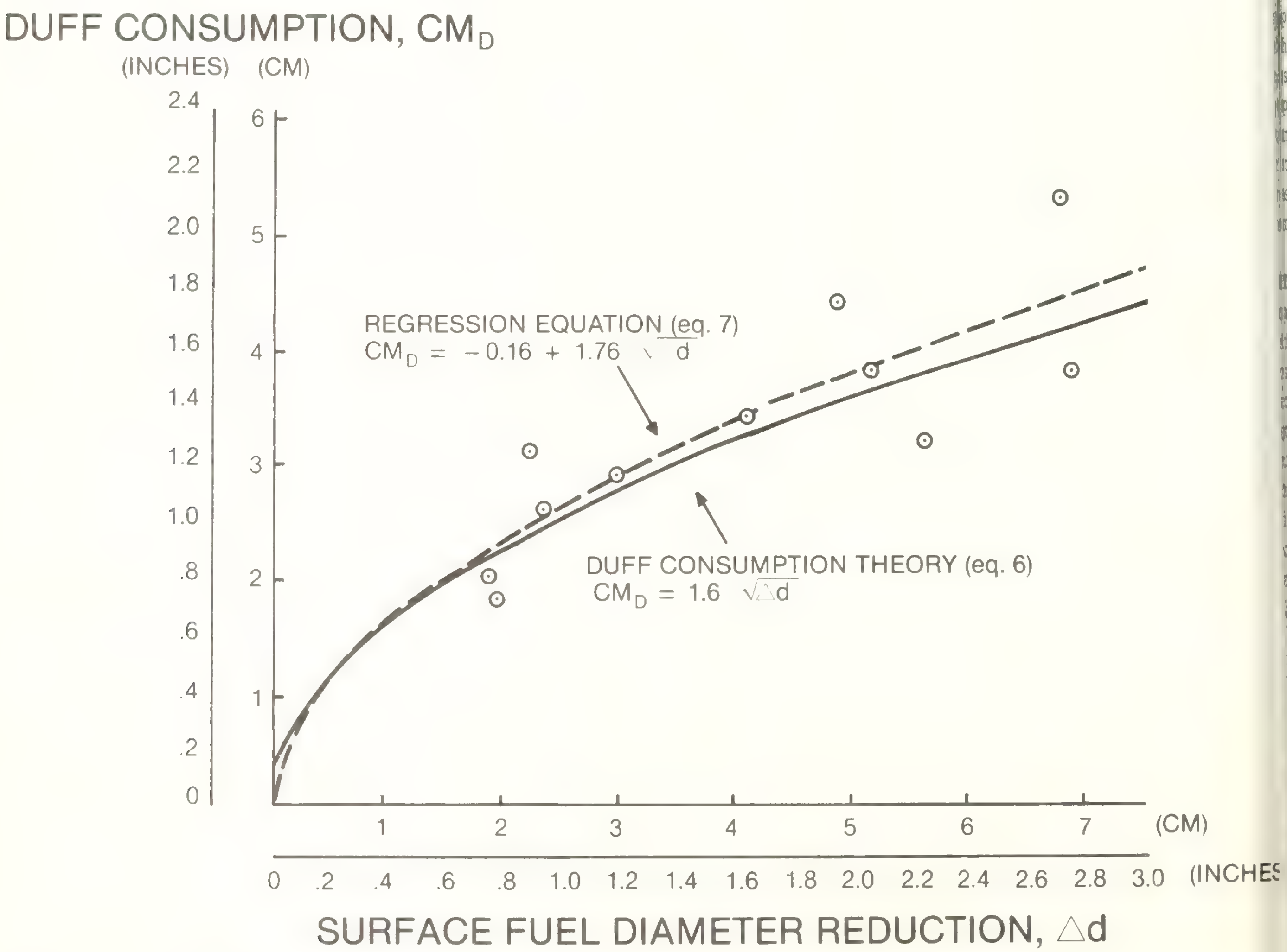

Figure 4.--Comparison of duff consumption with theory and with regression dependent on surface fuel diameter reduction. Analysis limited to fuel-dependent duff consumption.

ression Analysis.--NFDR estimates of sture content appear to be more useful oth a statistical and practical sense 1 collected samples of duff moisture ent. Most previous work, and common se, concludes that measured duff sture content is the most important erminant of duff consumption. Yet, in statistical analyses that follow, NFDR imates of fuel moisture are more ificant when used as independent iables. Duff moisture contents varied ly from point to point within a led unit. Our sampling procedures did allow stratification of the area into arate moisture regimes, which would been necessary for duff moisture to ear as a useful independent variable. difficulty of collecting samples will ally preclude use of the variable in rational use; and it is certainly asonable to expect field units to atify their collected data. NFDR imates, on the other hand, are inely available.

R fuel moisture estimates were compared to measured fuel moistures. Since NFDR system is not designed to repret conditions below tree canopies, the parisons are illustrative rather than a t of the efficacy of NFDR values. The parison is part of an ongoing study[4] will not be reported here in full. We establish in our partial cut stands, ever, that bivariate correlation fficients were highest with lower duff sture content, M_{L_D} (percent), for NFDR-Th fuel moistures than with any alternate timelag classes. Figure 5 compares NFDR-Th with M_{L_D}. No doubt the errors in prediction are due, at least in part, to NFDR-Th responding primarily to precipitation duration, while duff moisture is affected more by precipitation amount.

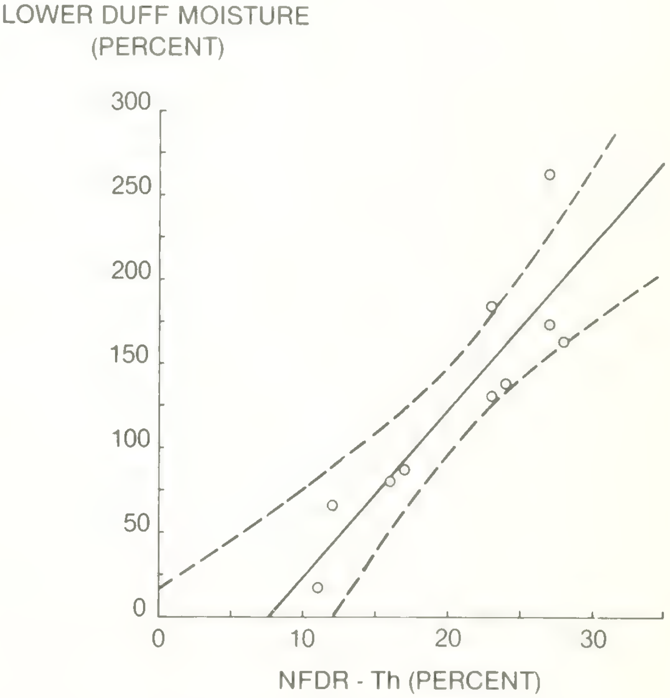

Figure 5.--Comparison of NFDR-Th fuel moisture with average duff moisture content.

NFDR-Th moisture content requires several weeks to stabilize to measured weather conditions, so fire weather stations in operation less than that period are of no value in predicting moisture contents in coarse fuels or duff. Other stations are closed in early fall, when much prescribed burning is done. Three units (K, BR, SP) are not shown in figure 5 because of such problems.

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tmar, R. D. 1979. Use of NFDR ices for prescribed fire planning. dy plan on file with Forest Residues gram, USDA Forest Service, Pacific thwest Forest and Range Experiment tion, Seattle, Washington.

Duff consumption was well fit by regressions on NFDR-Th alone (equation 8 and fig. 6). Units where duff burned independently of surface fuels (H2, P1) or where rainfall interrupted burning (TB) are excluded.

$$cm_D = 6.67-0.13 \text{ NFDR-Th (centimeters)} \quad (8)$$

$$N = 10;\ r^2 = 0.78;\ s_{\hat{y}.x} = 0.47 \text{ cm}).$$

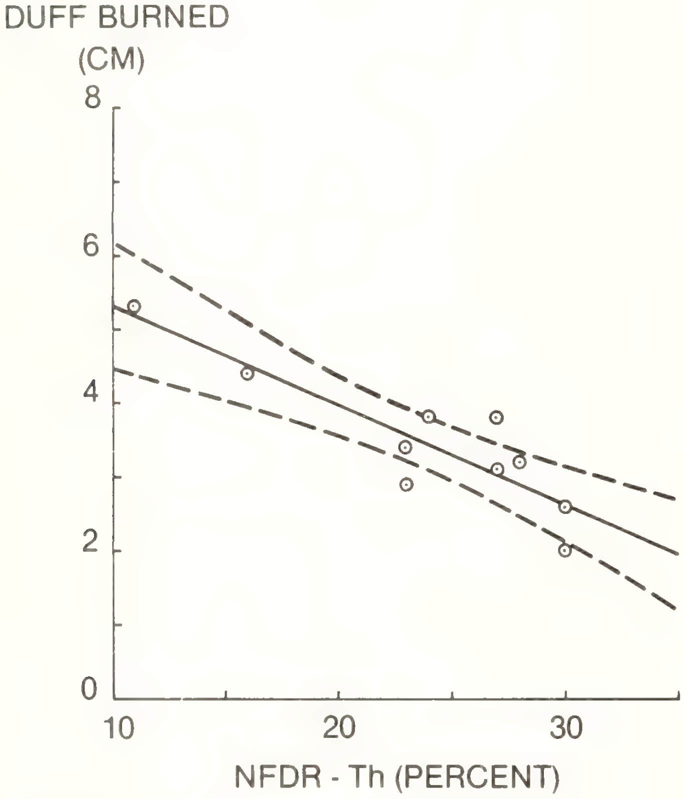


Figure 6.--Duff consumption in prescribed underburning experiments plotted against NFDR-Th fuel moisture content.

Duff Remaining

Regression Analysis.--The duff layer ness remaining after fire is commonly specified in prescribed burning objectives. Duff remaining, AFTDUFF imeters), was regressed on NFDR moistu contents and duff moisture contents. preburn duff thickness, BEFDUFF (cent- imeters), is used as an independent variable, the best fit is obtained in combination with NFDR-Th moisture cont

$$\text{AFTDUFF} = -6.76+0.99 \text{ BEFDUFF} + 0.14 \text{ NFDR-Th (centimeters)}. \quad (9)$$

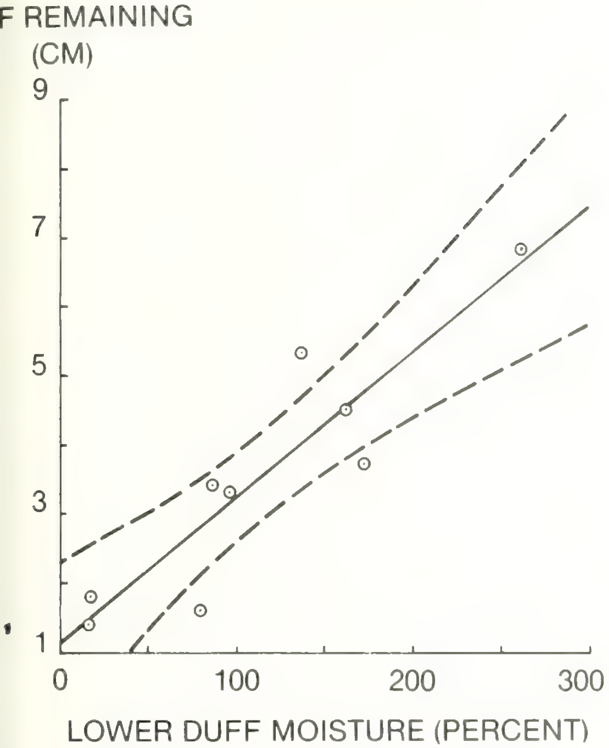
$$(N = 10;\ r^2 = 0.97;\ s_{\hat{y}.x} = 0.45 \text{ cm}).$$

Units where duff burned independently (H2, P1) or where rainfall interrupted burning (TB) are excluded. Equation 9 essentially a prediction of duff consu tion similar to equation 8 because the regression coefficient on BEFDUFF is n unity. When preburn duff thickness is used, it is necessary to exclude units (TB, A) where duff thickness exceeds 1 centimeters (4.1 inches) to obtain a regression significant at the 99-perce level (equation 10, fig. 7).

$$\text{AFTDUFF} = 1.24 + .02\ M_{L_D} \text{ (centimeters)}. \quad (10)$$

$$(N = 10;\ r^2 = 0.81;\ s_{\hat{y}.x} = 0.78 \text{ cm})$$

The constant term in equation 10 is si icant at the 95-percent level only.



ure 7.--Duff thickness remaining after e plotted against moisture content in lower one-half of the duff layer.

cent Duff Reduction

parison with Prior Work.--Shearer '5) and Norum (1977) presented pre- tion equations for percent duff uction based on lower duff moisture tent. The two algorithms are plotted igure 7, along with results of this dy. The two equations are similar at sture contents less than 110 percent, le Norum's predicts less duff reduction higher moisture contents. Our data ds to substantiate their results, ept at very low moisture contents. eement was best with Shearer's equation, likely because the range of preburn thickness is similar for the two lies. No improvement in fit was sible by adding fine fuel consumption an independent variable. Units (TB, A) where duff thickness was greater than 10.5 centimeters (4.1 inches) were excluded from figure 8, and the maximum of upper and lower duff moisture was used as our independent variable for this plot.

Regression Analysis.--Regression of percent duff reduction on duff moisture content provided no substantial improvement over the predictive algorithm provided by Shearer (1975), so we recommend that equation for use in Douglas-fir underburning.

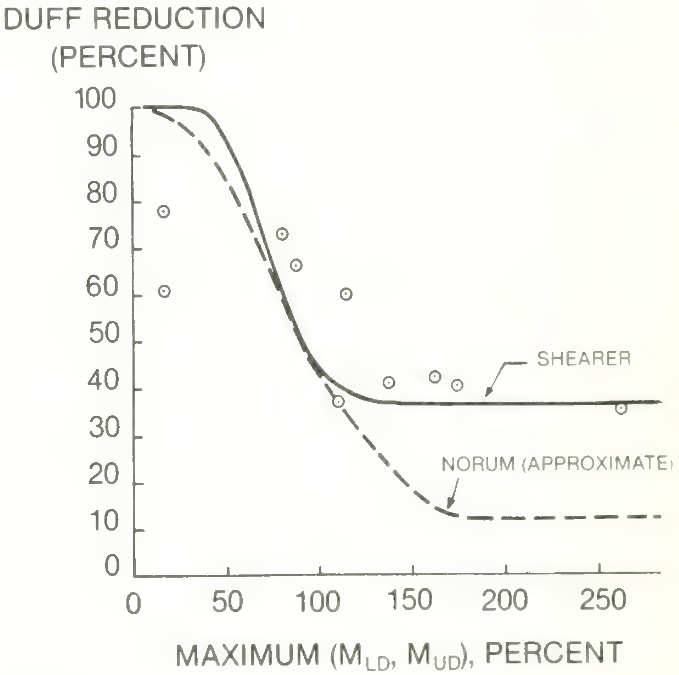


Figure 8.--Comparison of percent duff reduction with prediction algorithms by Shearer (1975), and Norum (1977). Duff thickness less than 10.5 cm.

The relationship between percent duff reduction, %D (percent), and NFDR-Th (percent), is demonstrated by figure 9. Units were excluded from analysis if preburn duff thickness exceeded 10.5 centimeters (TB, A), or where rainfall interrupted burning (TB, H2). The simple linear regression can be improved, albeit slightly, if the information is available to add NFDR 100-hour timelag fuel moisture in the NFDR-Hu (percent), or preburn duff thickness, BEFDUFF (cm), as an independent variable. All terms in the resulting predictive equations are significant at the 1-percent level.

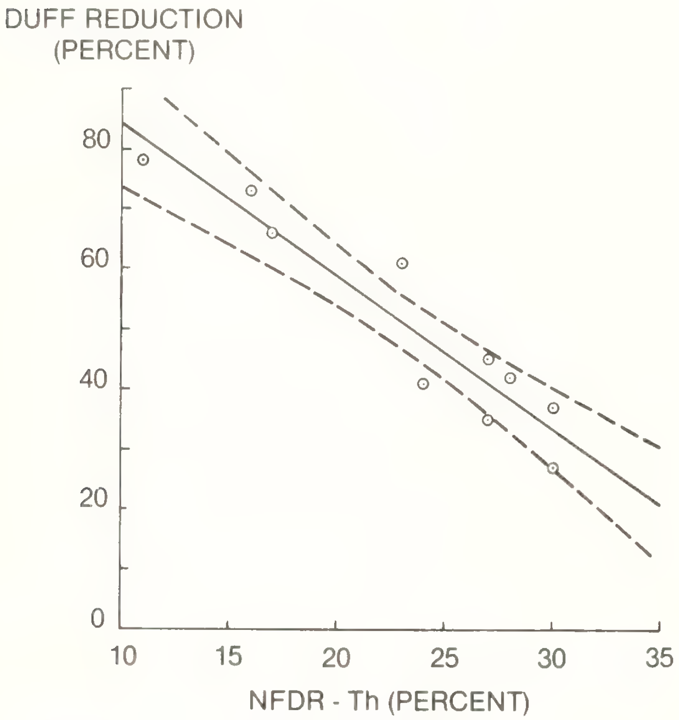


Figure 9.--Percent duff reduction during prescribed underburning experiments plotted against NFDR-Th fuel moisture content. Preburn duff thickness averaged 5.3 to 10.5 centimeters.

$\%D = 110 - 2.54$ NFDR-Th (percent),
($N = 10$; $r^2 = 0.89$ $s_{\hat{y}.x} = 6\%$)
$\%D = 133 - 2.05$ NFDR-Th $- 2.54$ NFDR-Hu (percent),
($N = 8$; $r^2 = 0.91$; $s_{\hat{y}.x} = 5\%$)
$\%D = 126 - 2.46$ NFDR-Th $- 2.33$ BEFDUFF (percent).
($N = 10$; $r^2 = 0.95$ $s_{\hat{y}.x} = 4\%$)

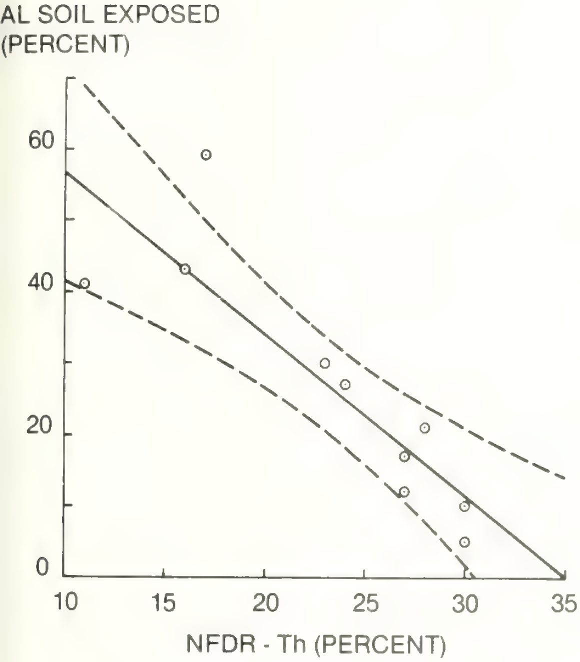
Mineral Soil Exposure

Comparison with prior work.--Attempts by Van Wagner (1972) and Chrosciewicz (1 to predict mineral soil exposure by regression analysis were largely unsu cessful. Norum's (1977) procedure is on the assumption that duff is remove an even layer all across a burned are assumption he substantiates by report typical standard deviations of duff d reduction on the order of 2 centimete (0.8 inches). We were unable to substantiate his results, however; no doubt because of the greater disturba by logging in our stands, which result in more variable duff consumption. Standard deviations of duff reduction the partial cut stands averaged about centimeters (1.6 inches).

Regression analysis.--The percentage c mineral soil exposed increased an aver of 22 percent by burning. Soil exposu %B (percent), was regressed on NFDR-Th (fig. 10). Units with thick duff ($\geq$10.5 cm) (TB, A) and those where rai interrupted burning (TB, H2) were excl

$\%B = 79 - 2.27$ NFDR-Th.

($N = 10$; $r^2 = 0.76$; $s_{\hat{y}.x} = 9\%$)



e 10.--Percent mineral soil exposed escribed underburning, plotted st NFDR-Th fuel moisture contents. rn duff averaged 5.3 to 10.4 centi-s thick.

al soil exposure was also compared to ent duff reduction (fig. 11). The ithm of mineral soil exposure was ssed on that of percent duff tion:

$$\text{ge}\ (\%B) = -0.08 + 2.12\ \log_e\ (\%D).$$

$$= 13;\ r^2 = 0.90,\ s_{\hat{y}.x} = 0.34)$$

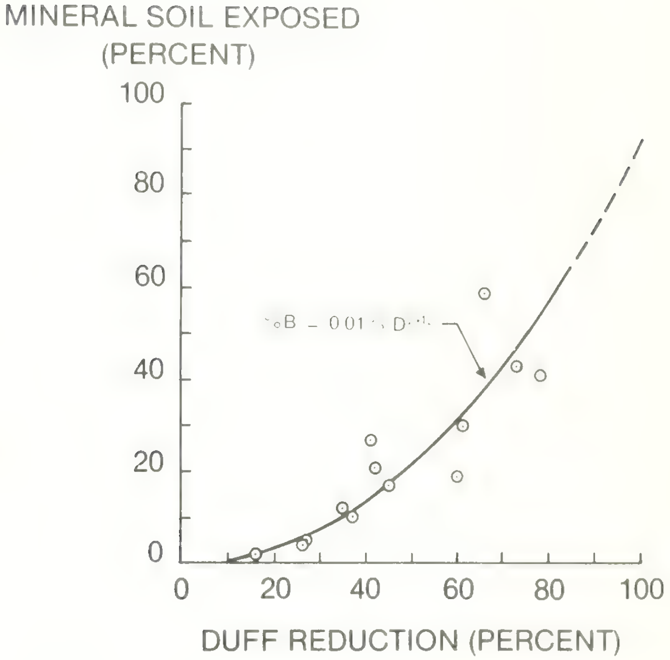


Figure 11.--Percent mineral exposure versus percent duff reduction.

No correction for possible bias was made in transforming this equation to the nonlinear form plotted in the figure. The figure may best be used to determine which objective is the greater constraint on planning a prescribed fire. For example, mineral soil to be exposed is typically specified as less than 20 percent. An objective to reduce duff by 50 percent or more would be in conflict with that specification.

Conclusion

The research reported here provides a means for prescribing weather and fuel moisture variables to attain a specified level of duff consumption. The amount (depth) of duff consumed or remaining, as well as the percentage of duff reduced or mineral soil exposed, may be specified. The NFDR-Th fuel moisture has the greatest utility as an independent variable. Predictability can be improved somewhat by adding preburn duff thickness, or duff (especially the lower one-half) moisture content as an independent variable.

The regression equations are generally valid for prescribed fires under partial cut Douglas-fir stands in western Washington and Oregon. Results were generally unpredictable if rainfall occurred within several hours after ignition. The equations predicting percentage duff reduction or mineral soil exposure are valid only where preburn duff is less than 10.5 centimeters (4.1 inches). Duff depth consumed or remaining after fire is underestimated by the equations when the duff is dry enough to burn independently of a surface fire. Prior research, substantiated here, suggests that this occurs when the upper duff moisture content is less than 30 percent, or when NFDR-Th is less than 18 percent. Evidence that less than 40 percent of duff is reduced with less than 15-percent mineral soil exposure and when lower duff moisture content exceeds 110 percent is corroborated.

Consumption of moist duff (greater th 30-percent moisture content) is depen upon, and well correlated with, eithe amount of woody fuel consumed or the duration of surface fire. Our result best explained by the depth of heat p tration in a simple conducting solid during surface fire duration. The la is apparently dried to a depth propor to the square root of fire duration, consumed to that depth by a smolderin fire.

The sensitivity of the results to NFD fuel moisture contents should facilit prescribed fire planning and smoke ma ment reporting. An average 0.13 cent (0.05 inch) of duff is consumed for e decrease of 1 percent in NFDR-Th. If specific gravity of duff is 0.165, th 0.22 kilograms per square meter (1 to acre) additional duff is consumed. A average 2.5-percent additional duff i reduced, and 2.3-percent additional s is bared. The difference between a sp and fall burn, with a typical differe of 15 to 20 percent in NFDR-Th, can re in as much as 4.4 kilograms per square meter (20 tons per acre) consumed and 45-percent mineral soil exposure. Obviously, specifying duff consumptio when writing burning prescriptions ca the most important determinant of site preparation and off-site (i.e., air an water) effects.

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Predictive equations for duff reduction and mineral soil exposure by prescribed fire are presented. An explanation is suggested for the dependence of duff combustion on surface fuel combustion. Surface fire duration and fuel moisture estimates of the National Fire-Danger Rating 1,000-hour timelag are the best predictors for reduction in moist duff. Duff layers with less than 30-percent moisture burned independently of surface fires.

Keywords: Duff, fire effects, prescribed burning, site preparation.

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Research Paper PNW-273
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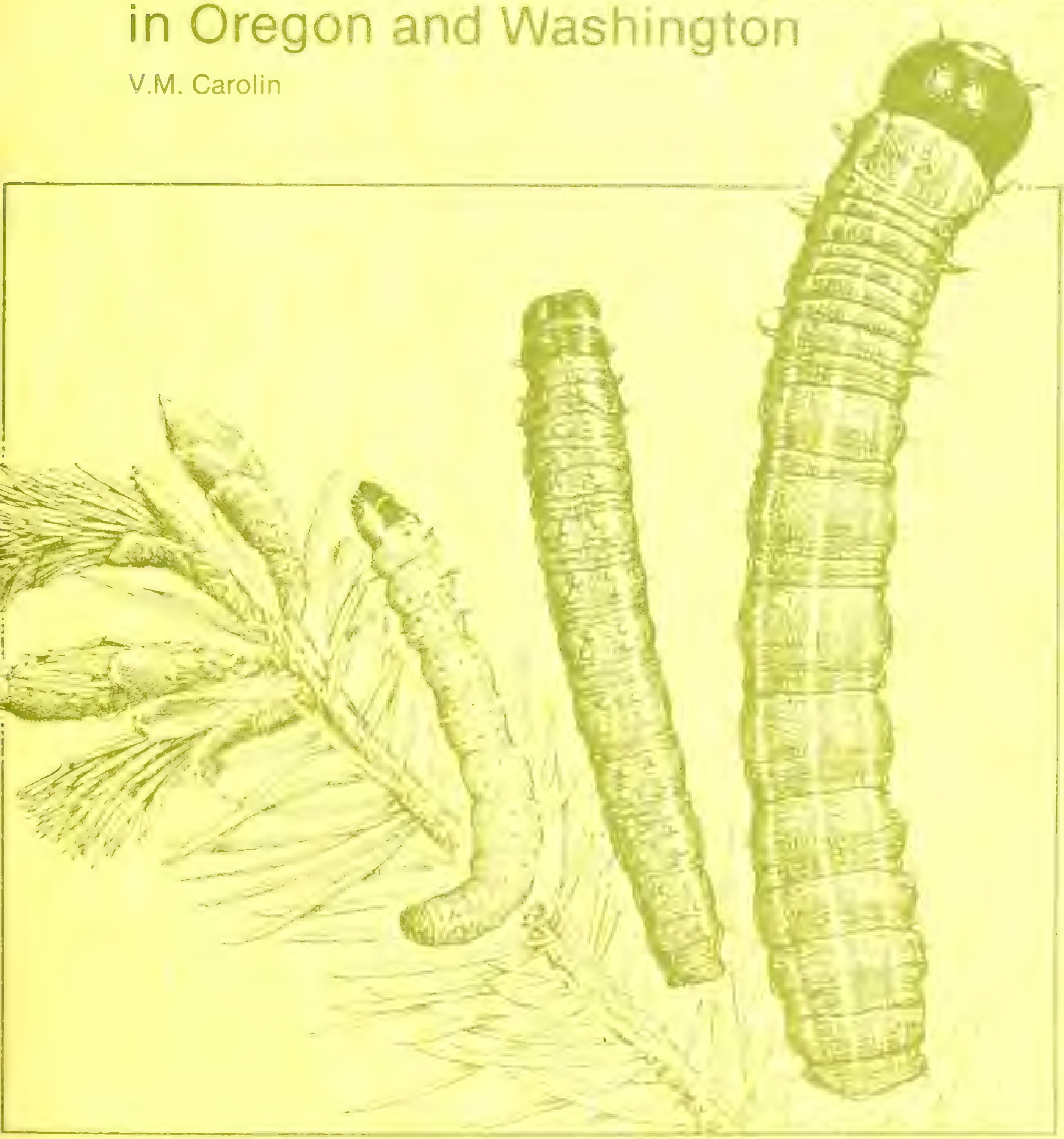
Larval Densities and Trends of Insect Species Associated With Spruce Budworms in Buds and Shoots in Oregon and Washington

V.M. Carolin



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V. M. Carolin

ference Abstract

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PNW-273, 18 p. Pac. Northwest For. and Range
Station, Portland, Oregon.

pling studies on western spruce budworm
Modoc budworm disclosed a substantial
ber of associated insect species at the time
e were in opening buds. About 20 species
r with sufficient regularity to justify identi-
ion by field crews.

ewords: Insect populations, reproductive
avior (insect), western spruce budworm, iden-
ation (insect), *Choristoneura occidentalis*,
doc budworm, *Choristoneura viridis*.

Research Summary

Research Paper PNW-273

1980

Densities and trends of insect species feeding in opening buds with the western spruce budworm, *Choristoneura occidentalis* Freeman, in Oregon and Washington, were analyzed for the period 1951 through 1962. During sampling at fixed plots for *C. occidentalis* in both sprayed and unsprayed areas, larvae of associated insect species were identified and quantified as numbers per one hundred 15-inch twigs. A similar but lesser effort was made in 1960-62 in unsprayed infestations of the Modoc budworm, *C. viridis* Freeman, in southern Oregon.

The various associated insect species and their frequencies on Douglas-fir, grand fir, and white fir are tabulated. Trends of six major associates at Douglas-fir and subalpine fir plots are shown graphically by study area; periods covered are 1951-59 for sprayed areas and 1955-58 for unsprayed areas. Major associates were: *Acleris gloverana* (Walsingham), *Argyrotaenia dorsalana* (Dyar), *Coleotechnites* sp., near *piceaella* (Kearfott), *Dioryctria reniculelloides* Mutuura and Munroe, *Griselda radicana* (Heinrich), and *Zeiraphera hesperiana* Mutuura and Freeman. Approximate trends in an infestation in the eastern Washington Cascades during 1960-62 and before spraying were deduced.

Indications as to preference of associated insect species for Douglas-fir and grand fir were obtained from two paired tree studies, one in northeast Oregon and one in the eastern Washington Cascades. Preference for Douglas-fir was shown by two associated species, and preference for grand fir by three associated species.

About 20 associated species occurred with sufficient frequency to justify their recognition as a routine part of sampling studies. Major peaks for most associates occurred in 1957 or 1958, along with the western spruce budworm.

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oduction

series of outbreaks by the western spruce bud- , *Choristoneura occidentalis* Freeman, have been way in parts of the West. In 1973, infestations red to be increasing in Oregon, Washington, Ari- New Mexico, and Colorado, although decreasing northern Rocky Mountains (Chansler and Toko . As of 1973, the eastern counterpart – the budworm, *C. fumiferana* (Clemens) – had ed large areas in the State of Maine, eastern a, and the Lake States; and aerial control proj- vere underway. Concern over the prospects of pread damage by these budworms led to the ion in 1977 of a 6-year cooperative program en the United States and Canada, with a mission veloping management strategies for controlling budworms, or learning to manage budworm- tible forests.

f the program objectives is to develop and ve methods for assessing and predicting bud- population levels. Such determination requires ssociated defoliators be recognized and that any ar relationships between spruce budworms and associates be defined. Evaluation of control iveness also demands that associated defoliators ntified in both pre-control and post-control ing. To this end, information on these associ- eeds to be made available to workers in the ng program.

ource of information is biological data obtained a previous budworm outbreak in Oregon and ngton. The major outbreak, mostly in the Blue tains and Cascade Range, began in 1947 and in 1959, after 4.7 million acres were sprayed DDT. A subsequent flare-up in the eastern Wash- n Cascades in 1959 was terminated in 1962 by spraying. Also in 1959, the Modoc budworm, *lis* Freeman,was found to be in epidemic status large area in southern Oregon and northern rnia. It reached a peak in 1960, then declined natural causes.

Biological studies starting in 1950 gradually disclosed the identity of the principal associated defoliators; subsequently, information on recognition of principal associated defoliators was made available to survey and control personnel in the form of hand-colored larval diagrams.[1] A publication on the effects of DDT spraying on the western spruce budworm (Carolin and Coulter 1971) included evidence of differential survival between the budworm and its associates.

Untapped data on associated defoliators in the files of the Pacific Northwest Forest and Range Experiment Station have recently been synthesized and analyzed. Comparisons were made between the frequency of occurrence of various associates on three different tree species, between trends of common associates in sprayed and unsprayed areas, including relationship to budworm trends, and between various associates as to host preference.

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[1] Unpublished report by V. M. Carolin and W. H. Klein, 1958, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Methods

Data Collection

Numbers of associated defoliators were recorded on foliage samples at spruce budworm study plots during the "larvae in the buds" stage, as defined by Carolin and Coulter (1972). Plot layout changed somewhat over the years, but sampling methods remained the same. The foliage sampling unit was the 15-in (38-cm) twig, removed from the lower half of the crowns of codominant firs by use of a six-section aluminum pole pruner, total length about 10.7 m (36 ft).

In 1951, 20 plots were established in areas sprayed with DDT either in 1949 or 1950, and three plots in unsprayed areas (Carolin and Wright 1953). Each plot had 10 subplots 100 m (about 330 ft) apart on a line; each subplot consisted of three sample trees. Ten 15-in (38-cm) twigs were cut from each sample tree; the total sample for the plot was 300 twigs. During 1952-54, the number of twigs per subplot was reduced to 10, taken from a variable number of sample trees. The total for the plot was 100 twigs. During this period, several of the plots in sprayed areas were decimated by logging, and two of the plots in unsprayed areas were scheduled for operational spraying in 1955.

In 1955 all plots retained in the sprayed areas, plus a replicate added in one area, and new plots in unsprayed areas were modified as to layout. Each plot now consisted of five subplots, still 100 m (330 ft) apart on a line, and each subplot consisted of five numbered trees from each of which four 15-in (38-cm) twigs were removed. In unsprayed areas, the tree sample was reduced to two twigs for very high budworm populations or when staminate flower production was heavy. Density was still expressed as number of larvae per 100 twigs.

Starting in 1959, when studies initiated in 1951 were phased out, all new plots installed were 10-tree or larger clusters. Number of twigs taken per tree ranged from two in very high populations to six in low populations. Larval density was now expressed both on a 100-twig basis and a 1,000-bud basis.

During the examination of twig samples, larva
unknown or uncertain identity were examined
a hand lens and given a temporary name, often
name, under which numbers were recorded. Sa
specimens were then placed in rearing. Large n
of a single species were reared in glass-topped b
on developing shoots supplied with water. S
numbers, usually one to four larvae, were reare
powderboxes with short twig sections bearing
foliage. All rearings were labelled as to tempo
name of the insect, plot at which collected, t
species, and collection date. The material was e
ined periodically, foliage replaced, and changes
appearance of the larvae noted. Material from p
sampled early in the season was reared in tran
most rearing was done at a field laboratory.

Adult specimens were mounted and labelled wi
tinent information. Most were assigned to num
collections under the Hopkins U.S. System; soli
specimens from a sampled locality were somet
given a Miscellaneous Number. Specimens were
sent to the Insect Identification and Parasite I
duction Branch, Agricultural Research Service,
determination. These determinations were late
in with the temporary insect names in our field

Occurrence of Associated Defoliators by Tree Species

Sampling records obtained when larvae were i
opening buds provided the main basis for comp
the occurrence of various associated defoliat
among tree species. During the early studies in 1
54, two different tree species were sampled at n
plots. Starting in 1955 only one tree species w
sampled at each plot, except for comparisons
densities of associated insects on paired tree spe

---

[2] The present name is the Insect Identification
Beneficial Insect Introduction Institute (SEA).

ayed areas during 1951-54, 76 records were
ied at plots having a mix of Douglas-fir (*Pseudo-*
menziesii (Mirb.) Franco) and grand fir (*Abies*
's (Dougl.) Lindl.), and four records at a plot
g mostly subalpine fir (*Abies lasiocarpa* (Hook.)
) with some Engelmann spruce (*Picea engelman-*
rry). During 1955-59, 44 records were obtained
ts in which only Douglas-fir was sampled, and
cords at plots in which only subalpine fir was
ed.

sprayed areas in northeastern Oregon during
54, 12 records were obtained at plots having a
le mix of Douglas-fir and grand fir sample trees;
st associations were shown for 1953. Then,
g 1955-59, 20 records were obtained at plots in
only Douglas-fir was sampled, and 1 record
ied for a paired Douglas-fir and grand fir plot.
unsprayed infestation in the eastern Washington
des during 1960-62, four records were obtained
ouglas-fir plots, five for grand fir plots, and one
paired Douglas-fir and grand fir plot.

unsprayed area in southern Oregon during
-62, during a study of the Modoc budworm, 14
records were obtained in white fir (*Abies con-*
(Gord. and Glend.) Lindl.) stands.

1962, supplemental information on associated
iators was obtained from the following sources:
eating plots in eastern Oregon; (2) studies in
rn Oregon on insects other than one of the
e budworms, but in which one of the budworms
n associate; (3) collections of opportunity.

l on plot records and supplemental information,
of species of associated defoliators were prepared
ree tree species – *A. grandis, A. concolor,* and
nziesii – and an index developed to show the
ve frequency at which these defoliators were
d. Terms to indicate relative frequency were:
non – occurring in nearly all plots every year;
ional – occurring in about half the plots every
sporadic – not found for a period of years, but
her years found in most plots; and rare – found
in one or two plots or locations in 1 or 2 years.

Trends of Associated Species

SPRAYED AREAS

Of the initial 20 plots established in sprayed areas, 10 were retained throughout the period of study (1951-59), and all were in Oregon. Distribution of the 10 plots by study areas was: Eugene (western foothills of the Cascades) – 3; Mount Hood (eastern slope of the Cascades in the Mount Hood National Forest) – 2; south Umatilla (southern part of the Umatilla National Forest, in the Blue Mountains) – 2; La Grande (Wallowa-Whitman National Forest, in the Blue Mountains) – 2; and north Umatilla (northern part of the Umatilla National Forest, in the Blue Mountains) – 1, with a replicate added in 1955. One of the Eugene plots was logged and not sampled in 1959 but is included in the record series. One of the Mount Hood plots was resprayed in 1952 but was retained.

Except for the north Umatilla area, sample trees during 1951-54 in the retained plots were mainly Douglas-fir, with a sprinkling of grand fir. In the north Umatilla area, sample trees during this period were primarily subalpine fir but included a few Engelmann spruce. Starting in 1955, sampling was restricted to Douglas-fir in four study areas and to subalpine fir in the north Umatilla area.

Trends for each associated defoliator were analyzed by (1) transferring the number of larvae per 100 twigs for each year to a summary sheet for the period 1951-59, (2) averaging these densities for plots in the same area, and (3) plotting the average density in each year over that year. Trends were compared for each major associate by area and for all major associates over the period 1951-59.

UNSPRAYED AREAS

Northeast Oregon. – Plots used in the Blue Mountains from 1951 through 1954 suffered various mishaps, including spraying and partial logging. In addition, records on associated defoliators and host relationships were often lacking. No reasonable analysis as to trends was possible.

Three new plots were established in 1955, and only Douglas-fir trees were sampled. The one remaining unsprayed plot was revamped so that only Douglas-fir was sampled. After sampling in 1957, this plot was discontinued because spruce budworm populations had dropped to a low level. A fifth plot was added this year. Three of the four plots remaining in 1958 were sprayed operationally that year, after plots were sampled. The fourth plot was sampled again in 1959, after which studies in the Blue Mountains were terminated.

Eastern Washington Cascades. – In 1960, four 10-tree cluster plots were established in the eastern Washington Cascades on part of the Yakima Indian Reservation near Goldendale. Two were in Douglas-fir stands and two were in grand fir stands. All four plots were sampled both in 1960 and 1961; the 1961 record for one of the grand fir plots was lost. A fifth plot was established in 1961, with grand fir being sampled. In 1962, just before operational spraying, one of the original grand fir plots was sampled, and at the edge of the plot newly installed in 1961, paired Douglas-fir and grand fir trees were sampled. Because of the short duration of study, possible trends of associated defoliators were approximated from a tabulation which listed larval densities by plot and year.

Southern Oregon. – Also in 1960, a study on the Modoc budworm used four 10-tree clusters of white fir in each of two subareas: the North Warner Mountains and the Gearhart Mountains. In 1961 half of the plots in each subarea were again sampled. In 1962 only one of the original plots was sampled. Possible trends of associates were approximated by a simple tabulation of replicated plots, showing larval densities by plot and year.

Host Preference

Preference of some associated defoliators betw Douglas-fir and grand fir was tested in 1959 a paired tree plot in northeast Oregon near Half Ten pairs of these two tree species were sample taking six 15-in (38-cm) twigs per tree; all ope buds or new shoots were counted on each 15-in Larval densities were expressed both as larvae p twigs and larvae per 1,000 opening buds. Densit seven associates occurring at a density of at le seven larvae per 100 twigs were compared bet the two tree species. In this same season, a follo was made when some of the associates were st feeding at the time spruce budworm larvae were grown. Four twigs were cut per tree and densi expressed on a 100-twig basis.

Preference for either Douglas-fir or grand fir w again tested in 1962 in a paired plot comparison the eastern Washington Cascades near Goldend Five pairs of trees were sampled, and we took o four twigs per tree because of very high number western spruce budworm. Numbers of opening b on each twig were again counted. Larval densit were expressed on the same two bases as at the H way plot.

In our studies on the Modoc budworm in sout Oregon, no paired tree comparisons were possib The host tree species was exclusively white fir; Douglas-fir occurred in the two subareas in wh studies were conducted.

esults

currence of Associated foliators by Tree Species

st of the defoliators associated with western spruce worm on Douglas-fir were also associated with species on grand fir and with the Modoc budworm white fir (tables 1-3). Some species not recorded grand fir and white fir in our study areas are listed *Vestern Forest Insects* (Furniss and Carolin 1977) ccurring on these hosts or on "true firs."

MMON AND OCCASIONAL ASSOCIATES

ociates common on all three tree species were *yrotaenia dorsalana* (Dyar), *Dioryctria reniculelles* Mutuura and Munroe, and *Griselda radicana* inrich). *Acleris gloverana* (Walsingham) was comn on these three hosts from 1957 through 1960 was sporadic from 1951 to 1956. A gelechiid, *eotechnites* near *piceaella* (Kearfott), was common Douglas-fir but was rare or occasional on the two firs. Another gelechiid, in the *Chionodes-Telsa* complex, was common on grand fir and white out only occasional on Douglas-fir. An olethreutid, *raphera hesperiana* Mutuura and Freeman, was the st common associate on Douglas-fir; a different unidentified species of *Zeiraphera* was common grand fir and occasional on white fir.

iprionid sawfly, *Neodiprion* sp., was occasionally nd in small loosely knit colonies on the new shoots Douglas-fir; larvae start to feed as soon as the bud is off. A webspinning sawfly, *Acantholyda* sp. mphiliidae), was occasional on grand fir, common white fir, but rare on Douglas-fir. One or more lid sawflies in the genus *Pleroneura* were found on firs, and most commonly on white fir. The larvae three species of *Pleroneura* on white fir in Calinia cannot be separated morphologically (Ohmart Dahlsten 1977).

RE AND SPORADICALLY OCCURRING SOCIATES

ew and apparently rare species of *Choristoneura* collected as small larvae on both Douglas-fir and nd fir at two study plots in the Cascades. Adult cimens are at the U.S. National Museum.

Loopers feeding on new growth were generally rare. The two species found most often were *Eupithecia annulata* (Hulst) and *Enypia* sp. near *griseata* Grossbeck; both were on Douglas-fir, grand fir, and white fir. Three loopers which occur in coastal forests and interior wet belt forests were recorded in other studies. The western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst), was collected from grand fir during a spruce budworm damage study in the Snake River area of Oregon. It is an occasional associate of *C. occidentalis* in the northern Rocky Mountains. The phantom hemlock looper, *Nepytia phantasmaria* (Strecker), was accompanied by *C. occidentalis* in a small outbreak on Douglas-fir in parklike settings near Portland, Oregon, during 1964-65. The greenstriped forest looper, *Melanolophia imitata* (Walker), occurs mostly in coastal areas, with a species of *Choristoneura* sometimes present; it was commonly found in beatings of Douglas-fir in the northern Rocky Mountains (Volker 1978).

Several noctuids occurred rarely or sporadically. The two species found most often were *Achytonix epipaschia* (Grote) and *Xylomyges simplex* (Walker), on Douglas-fir and white fir.

Trends of Associated Species

SPRAYED AREAS

Long-term trends were evident in most study areas for six associated species: *Acleris gloverana*, *Argyrotaenia dorsalana*, *Coleotechnites* near *piceaella*, *Dioryctria reniculelloides*, *Griselda radicana*, and *Zeiraphera hesperiana* (figs. 1-6). In addition, *Achytonix epipaschia* and *Xylomyges simplex* (Noctuidae) and a combination of all loopers (Geometridae) showed increases from obscurity from 1957 through 1959, without a clear indication of trend. Not recorded in these sprayed areas during the period of study was the Douglas-fir tussock moth, *Orgyia pseudotsugata*.

Table 1 — Defoliators associated with western spruce budworm in opening buds and new shoots on Douglas-fir in Oregon and Washington

Order, family, and species	Locality	Occurrence
HYMENOPTERA		
Diprionidae		
Neodiprion sp.	E. Oreg. and Wash.	Occasional
Pamphiliidae		
Acantholyda sp.	E. Oreg. and Wash.	Rare
LEPIDOPTERA		
Gelechiidae		
Chionodes spp.	Oreg. and Wash.	Occasional
Coleotechnites sp. near *piceaella* (Kearfott)	Oreg. and Wash.	Common
Coleotechnites sp.	Eugene, Oreg.	Rare
Geometridae		
Enypia sp. near *griseata* Grossbeck	E. Oreg. and Wash.	Rare
Eupithecia annulata (Hulst)	Oreg. and Wash.	Occasional
Lambdina fiscellaria lugubrosa (Hulst)	N.E. Oreg. and S.W. Wash.	Sporadic
Melanolophia imitata (Walker)	S.W. Wash.	Sporadic
Nepytia phantasmaria (Strecker)	W. Oreg.	Sporadic
Stenoporpia n. sp.	Eugene, Oreg.	Rare
Lymantriidae		
Orgyia pseudotsugata (McDunnough)	E. Oreg. and Wash.	Sporadic
Noctuidae		
Achytonix epipaschia (Grote)	Oreg. and Wash.	Sporadic
Anomogyna mustelina Smith	E. Oreg.	Rare
Xylomyges simplex (Walker)	Oreg. and Wash.	Sporadic
Olethreutidae[1]		
Griselda radicana (Heinrich)	Oreg. and Wash.	Common
Zeiraphera hesperiana Mutuura and Freeman	Oreg. and Wash.	Common
Plutellidae		
Ypsolopha (Abebaea) sp., prob. *cervella* (Walsingham)	Eugene, Oreg.	Rare
Pyralidae		
Dioryctria abietivorella (Grote)	Eugene, Oreg.	Rare
Dioryctria reniculelloides Mutuura and Munroe	Oreg. and Wash.	Common
Tortricidae		
Acleris gloverana (Walsingham)	Oreg. and Wash.	Sporadic/common
Archips sp.	Eugene, Oreg.	Rare
Archips sp.	Baker, Oreg.	Rare
Argyrotaenia dorsalana (Dyar)	Oreg. and Wash.	Occasional-commo
Argyrotaenia provana (Kearfott)	Oreg.	Rare
Choristoneura rosaceana (Harris)	W. Oreg.	Sporadic
Choristoneura n. sp.	Eugene, Oreg. and Goldendale, Wash.	Rare
Clepsis persicana (Fitch)	Baker, Oreg.	Rare
Walshiidae		
Periploca sp.	Baker, Oreg.	Rare

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[1] Sometimes considered a subfamily, Olethreutinae, in the Tortricidae.

le 2 — Defoliators associated with western spruce budworm in opening buds and new shoots rand fir in Oregon and Washington

er, family, and species	Locality	Occurrence
MENOPTERA		
amphiliidae		
Acantholyda sp.	E. Oreg. and Wash.	Occasional
yelidae		
Pleroneura spp.	Oreg. and Wash.	Rare/occasional
IDOPTERA		
elechiidae		
Chionodes sp.	E. Oreg. and Wash.	Occasional
Coleotechnites sp. near *piceaella* (Kearfott)	Oreg. and Wash.	Rare
Telphusa sp.	Oreg. and Wash.	Rare
eometridae		
Enypia sp. near *griseata* Grossbeck	E. Oreg.	Rare
Eupithecia annulata (Hulst)	Oreg. and Wash.	Rare
Gabriola sp. near *minima* (Hulst)[1]	E. Oreg.	Rare
Lambdina fiscellaria lugubrosa (Hulst)	N.E. Oreg.	Rare
ymantriidae		
Orgyia pseudotsugata (McDunnough)	E. Oreg. and Wash.	Sporadic
octuidae		
Anomogyna sp.	E. Oreg.	Rare
Syngrapha sp.	E. Oreg.	Rare
lethreutidae[2]		
Griselda radicana (Heinrich)	Oreg. and Wash.	Common
Zeiraphera improbana (Walker)	E. Oreg.	Rare
Zeiraphera sp.	E. Oreg. and Wash.	Common
yralidae		
Dioryctria reniculelloides Mutuura and Munroe	Oreg. and Wash.	Common
ortricidae		
Acleris gloverana (Walsingham)	Oreg. and Wash.	Sporadic/common
Argyrotaenia dorsalana (Dyar)	Oreg. and Wash.	Occasional-common
Choristoneura n. sp.	Goldendale, Wash.	Rare

is species was found on subalpine fir, but presumably occurs on grand fir.

metimes considered a subfamily, Olethreutinae, in the Tortricidae

Table 3 – Defoliators associated with Modoc budworm in opening buds and new shoots on white fir in southern Oregon

Order, family, and species	Occurrence
HYMENOPTERA	
Pamphiliidae	
Acantholyda sp.	Common
Xyelidae	
Pleroneura spp.	Common
LEPIDOPTERA	
Gelechiidae	
Chionodes sp.	Common
Coleotechnites sp. near *piceaella* (Kearfott)	Occasional
Telphusa sp.	Rare
Geometridae	
Enypia sp. near *griseata* Grossbeck	Rare
Lymantriidae	
Orgyia pseudotsugata (McDunnough)	Rare
Noctuidae	
Achytonix epipaschia (Grote)	Occasional
LEPIDOPTERA (continued)	
Noctuidae (continued)	
Syngrapha sp.	Rare
Xylomyges simplex (Walker)	Occasional
Olethreutidae[1]	
Griselda radicana (Heinrich)	Common
Zeiraphera sp.	Occasional
Pyralidae	
Dioryctria reniculelloides Mutuura and Munroe	Common
Tortricidae	
Acleris gloverana (Walsingham)	Sporadic/com
Archips sp.	Rare
Argyrotaenia dorsalana (Dyar)	Occasional-co

[1] Sometimes considered a subfamily, Olethreutinae, in the Tortricidae.

Major peaks for the six principal associated species, with the possible exception of *Acleris gloverana*, were in 1957 or 1958; peaks for the western spruce budworm in these same sprayed areas have been reported for these same 2 years (Carolin and Coulter 1971; also see table 4, appendix). At the nine Douglas-fir plots, the greatest increase in numbers of all associates (excluding colonies of *Neodiprion* sp.) occurred between 1956 and 1957: 385 to 627 specimens, or an increase of 63 percent. Between 1957 and 1958, a decrease of 27 percent took place. At the two subalpine fir plots, the greatest percentage increase was 209 percent between 1956 and 1957, starting from a low density. It was followed by a 129-percent increase in 1958, and a 12-percent decrease in 1959.

Zeiraphera hesperiana was the most abundant species in these plots. Its density before spraying was not recorded but may have been substantial. It reached low ebb in all five sprayed areas during 1953 and 1954, then increased to either a peak or plateau 1957. Thereafter, three areas showed about the densities through 1959; two others showed a s decrease in 1959 (fig. 1). The highest densities b were in the Eugene area: 52-53 larvae per 100 t in 1957 and 1958.

Acleris gloverana was not recorded at the Dougl plots from 1951 to 1955. Several larvae were fo during 1956 to 1959, with the highest density a single plot being six larvae per 100 twigs. An inc was evident but the data failed to show year-to- trends for individual areas. At the subalpine fir trends were distinct. Starting in 1955, density creased steadily and reached a peak in 1958 at o plot, and in 1959 at the other plot (fig. 2). Duri these peaks, damage to foliage was readily visib from the ground. This flare-up followed by 1 ye extensive outbreak of *Acleris gloverana* on 237 acres of western hemlock and true fir in wester Washington.

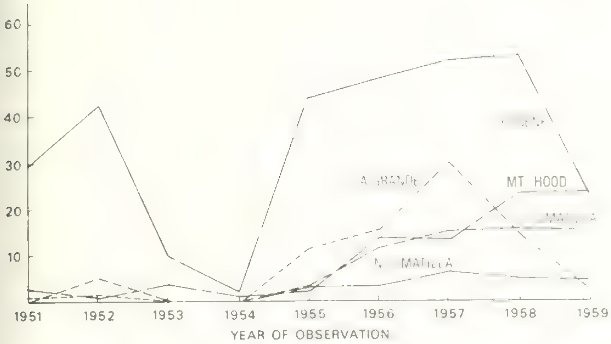

Figure 1.— Trends in density of Zeiraphera hesperiana *larvae on Douglas-fir and subalpine fir in sprayed areas.*

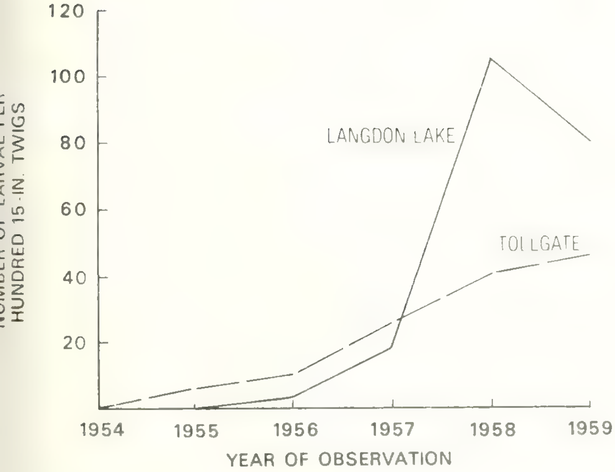

Figure 2. — Trends in density of Acleris gloverana *larvae on subalpine fir in two sprayed plots.*

Argyrotaenia dorsalana was at a very low level from 1951 to 1954. In 1951 it was recorded at only two plots. During 1952-54, some of the associated larvae were not identified, and *A. dorsalana* may have been overlooked. Starting in 1955, this species was found in all four Douglas-fir areas, but not in the subalpine fir area. A number of larvae were reared each year to assess variation; very few were found to be *A. provana.* Entries on the field forms were corrected for this incidence. From 1955 to 1959, *A. dorsalana* was found at average densities up to 3.5 larvae per 100 twigs. Although these are low densities, the two areas in the Blue Mountains (La Grande and south Umatilla), both sprayed in 1950, appear to show similar trends, with an early peak in 1955 and then peaking either in 1957 or 1958. The Mount Hood area showed a peak in 1958, and the Eugene area showed a strong upswing in 1959, possibly reaching a peak (fig. 3).

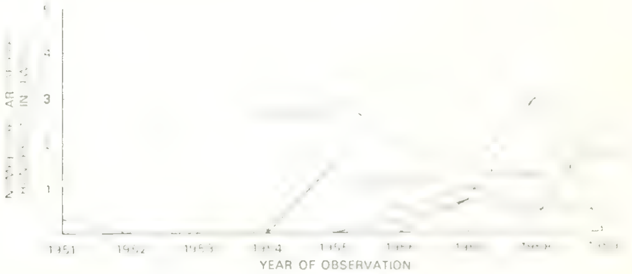

Figure 3. — Trends in density of Argyrotaenia dorsalana *larvae on Douglas-fir in sprayed areas.*

Coleotechnites near *piceaella* oscillated at a low population density in the Douglas-fir areas during 1951-56. All areas showed a strong increase in 1957; and three of these showed population peaks in 1958, followed by a decline in 1959 (fig. 4). The peak in the Eugene area was a year later. Only one specimen of *Coleotechnites* was found in the subalpine fir area, and it is possible that this was not the same species.

Dioryctria reniculelloides, the spruce coneworm, was found in all five sprayed areas and in all plots but one in 1951. During 1952-54, it was at a very low density in all plots, followed by a resurgence in two of the Douglas-fir areas in 1955. In 1957 it showed a strong peak in three of the Douglas-fir areas, and a strong decline thereafter (fig. 5). No trend was evident in the fourth Douglas-fir area, Mount Hood, nor in the subalpine fir (north Umatilla) area; only one specimen was found in each of these two areas during 1955-59.

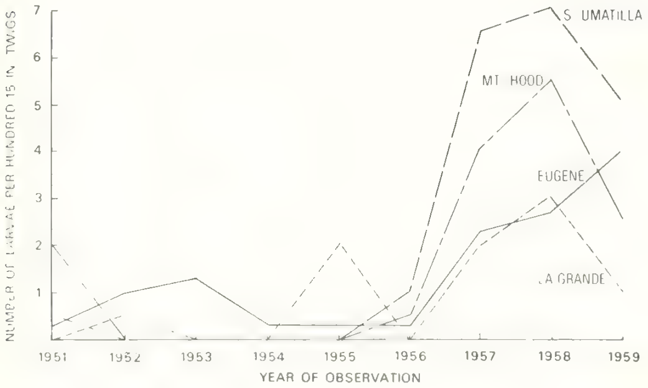

Figure 4. — Trends in density of Coleotechnites *sp. near* piceaella *larvae on Douglas-fir in sprayed areas.*

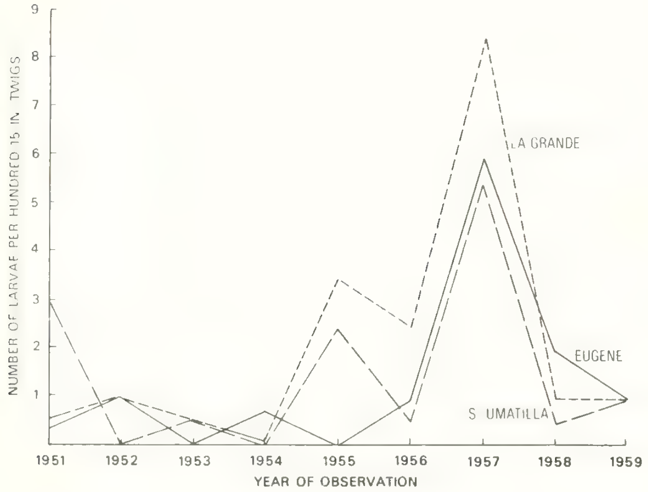

Figure 5. — Trends in density of Dioryctria reniculelloides *larvae on Douglas-fir in sprayed areas.*

Griselda radicana, the spruce tip moth, was one o the two most common associates of the spruce budworm in these sprayed areas. Its numbers oscillated a low level in all areas until 1955, when it showed strong increase in the La Grande area. Subsequentl this species showed peaks in 1957 in three of the Douglas-fir areas and in the subalpine fir area, with the La Grande area showing the strongest peak (fig. 6). The fourth Douglas-fir area, Mount Hood which showed low densities throughout the study period, showed a small peak in 1958, which may b an artifact of sampling.

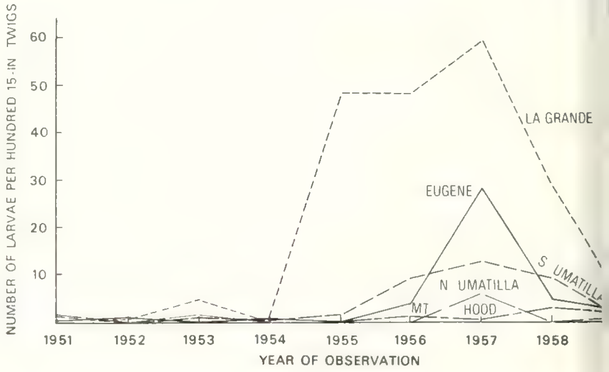

Figure 6. — Trends in density of Griselda radican *larvae on Douglas-fir and subalpine fir in sprayed are*

Achytonix epipaschia and *Xylomyges simplex,* tw noctuids of potential significance in western forests were not recorded in these sprayed areas until 1957 During 1957-59 both species were found in the Eugene and Mount Hood areas at average densities up to 3.5 larvae per 100 twigs, and *A. epipaschia* in the south Umatilla area at average densities up to 3. per 100 twigs. Neither species was recorded in the La Grande study area, but *A. epipaschia* was record in the north Umatilla subalpine fir area in 1958. In 1964 these species caused noticeable defoliation o Douglas-fir on 8,400 acres in western Oregon (Orr et al. 1965).[3]

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[3] Both noctuid species were found in this infestatio although only *Xylomyges simplex* is mentioned in t report. Specimens were identified by V. M. Carolin.

oopers (Geometridae) on opening buds and new ioots were mostly rare – one specimen in 1951 and one for 1952-55. Subsequent recoveries in number f specimens found at the 11 plots were: 1956 – 2, 957 – 13, 1958 – 4, and 1959 – 3. The species found ost often was *Eupithecia annulata,* which com- ences feeding on the opening bud in the conceal- ent of the bud sheath. It was found in three of the rayed areas.

NSPRAYED AREAS

ortheast Oregon. – Trends of major associated ecies from 1955 to 1958 were similar to those shown the sprayed areas, particularly those in northeast regon, for the same period. Only one of the six ecies showing discernible trends in the sprayed reas – *Coleotechnites* near *piceaella* – failed to occur ith sufficient frequency to provide a comparison.

ajor peaks for five associates were in 1957 or 1958, s in the sprayed areas. The total numbers of speci- ens of all associates at four plots increased from 24 to 1,005 between the years 1956 and 1957 – a 10-percent increase. The number of specimens then ecreased 44 percent between 1957 and 1958.

eiraphera hesperiana was the most abundant associ- ted species. In 15 of the 16 plot years represented y these four plots, its density was 2 to 16 percent of at of the western spruce budworm. In the remaining lot year, 1957 at Chesnimnus, its density was 68 ercent of that of a declining spruce budworm popu- tion. The highest density of *Z. hesperiana* was in e Dale (south Umatilla) plot in 1957 – 206 larvae er 100 twigs amidst a very high spruce budworm opulation.

n upswing starting in 1955, as in the sprayed areas, as followed by a peak in 1957 at all plots (fig. 7). similar peak was shown in the La Grande sprayed rea in 1957, while a plateau was shown for the outh Umatilla sprayed area during 1957-59.

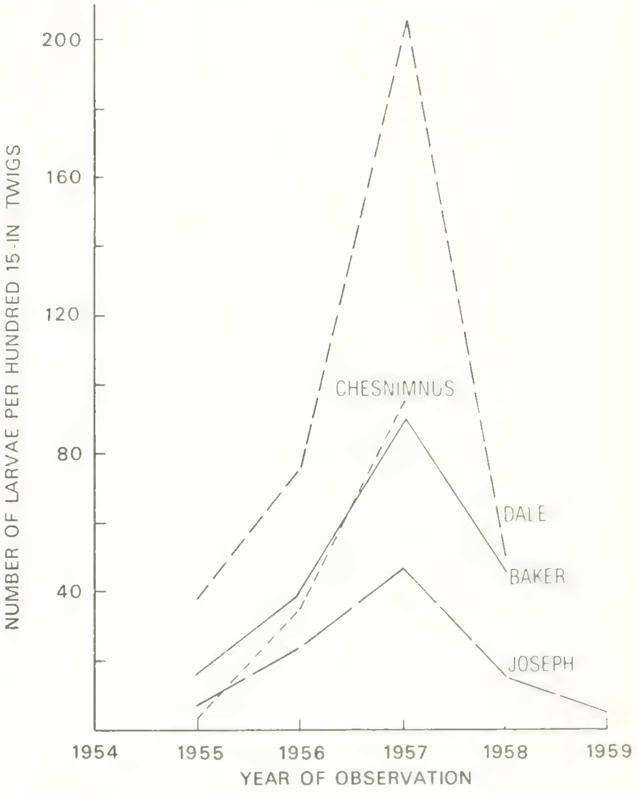


Figure 7. – Trends in density of **Zeiraphera hesperiana** *larvae on Douglas-fir in unsprayed areas.*

Acleris gloverana began an upward trend at two plots each in 1956 and 1957. Possible peaks were shown at the Baker and Dale plots in 1958 (fig. 8); collection of further data under existing conditions was terminated by operational spraying. At the Joseph plot in an area left unsprayed, a slow increase at a low level continued through 1959. At the Chesnimnus plot a small increase at a low level occurred in 1957; but this plot was dropped in 1958.

These four unsprayed Douglas-fir plots showed substantially higher densities of *A. gloverana* than were found in the four sprayed Douglas-fir plots in northeastern Oregon (south Umatilla and La Grande areas). Densities in the unsprayed plots were as high as 30 larvae per 100 twigs.

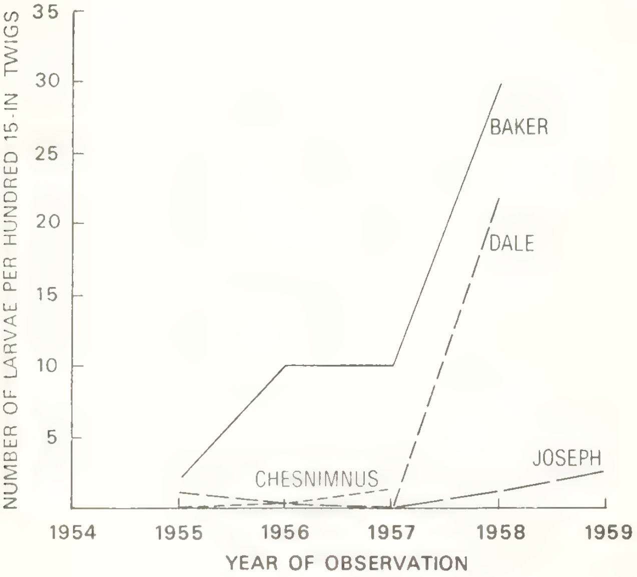


Figure 8. — Trends in density of **Acleris gloverana** *larvae on Douglas-fir in unsprayed areas.*

Argyrotaenia dorsalana showed a steady increase at two plots from 1956 to 1958; at the Joseph plot, left unsprayed, a decrease took place in 1959 (fig. 9). At a third plot, it oscillated at a low plateau during 1956-58; and at a fourth plot, it was at a very low density with no trend discernible. The overall pattern is much the same as in the sprayed plots in northeastern Oregon, except that no peak was evident in 1955.

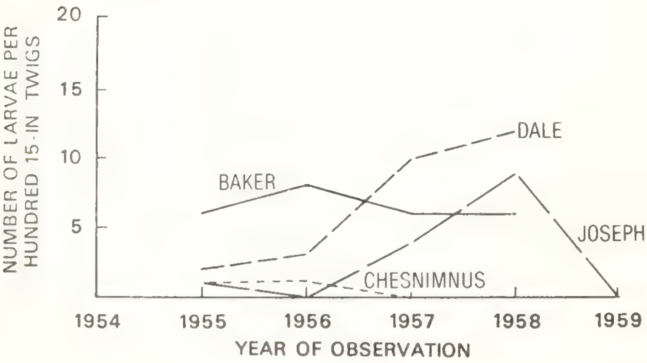


Figure 9. — Trends in density of **Argyrotaenia dorsalana** *larvae on Douglas-fir in unsprayed areas.*

Dioryctria reniculelloides showed strong peaks a
three plots in 1957, then declined in 1958 (fig. 10),
as in the sprayed areas. A slight resurgence was sho
in 1959 at one of these unsprayed plots. No tren
was evident at a fourth plot having a very low dens
Highest density of *D. reniculelloides* was at the Dal
(south Umatilla) plot in 1957 — 158 larvae per 10(
twigs, amidst a very high spruce budworm populati

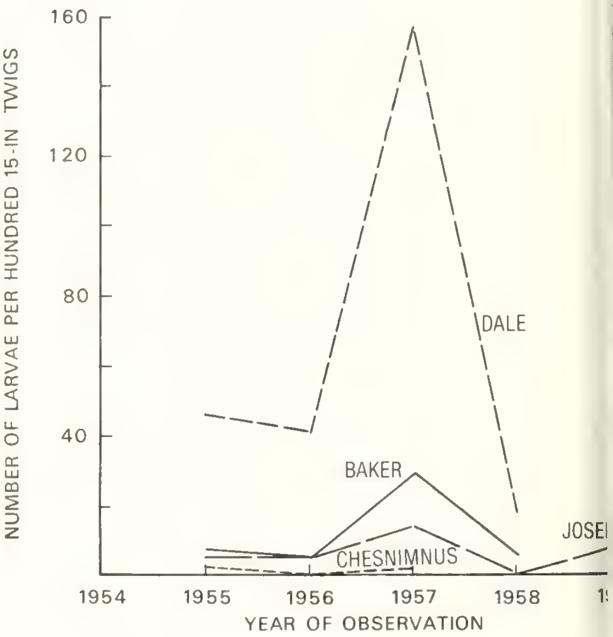
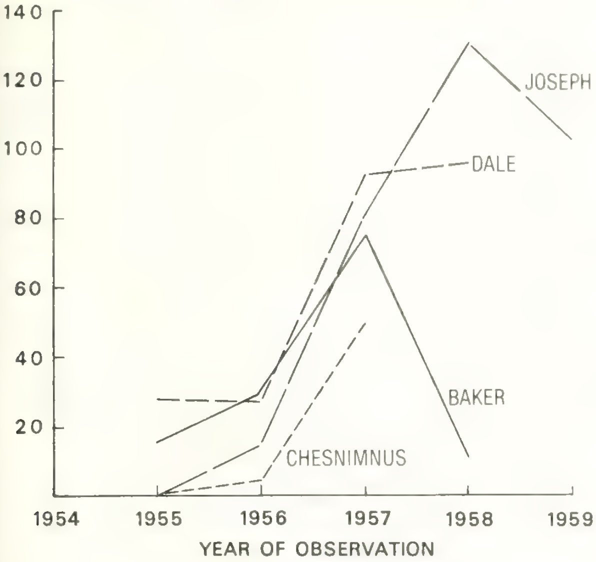


Figure 10. — Trends in density of **Dioryctria renicul loides** *larvae on Douglas-fir in unsprayed areas.*

Griselda radicana was second only to *Zeiraphera*
hesperiana in abundance, as it was in the sprayed
areas. It showed an increase in density between 195
and 1956, followed by peaks either in 1957 or 195
(fig. 11). Only the Baker plot showed a sharp peak
1957 as in the sprayed areas. At the Joseph plot, le
unsprayed, a decrease in density took place in 1959
Highest density of *G. radicana* was 131 larvae per 1
twigs, recorded at the Joseph plot in 1958.

Some other species or species groups were more
numerous in some years than in others, but trends a
individual plots were unclear. The principal gelechi
Coleotechnites near *piceaella* and species in the gen



igure 11. – Trends in density of Griselda radicana *rvae on Douglas-fir in unsprayed areas.*

hionodes, were most common in 1957 and 1958. *lchytonix epipaschia* and *Xylomyges simplex,* two octuids recorded in the sprayed areas during 1957-9, were found in the unsprayed plots only in 1957 nd 1958, and at low densities. Loopers (Geometriae) were recorded only in 1957 and 1958, and at ery low densities.

astern Washington Cascades. – The duration of the tudy in this area was too short for determining trends f most budworm associates. Trends were apparent, owever, for *Acleris gloverana* occurring on Douglasir and grand fir, and two species of *Zeiraphera,* one n Douglas-fir and the other on grand fir.

flare-up of *Acleris gloverana* on 24,500 acres 9 915 ha) in the Yakima Indian Reservation had been ecorded in 1957 (Whiteside 1958), and it persisted in nixture with the western spruce budworm on 9,960 cres (4 030 ha) in 1959 (Buckhorn and Orr 1959). t one grand fir plot in this area, sampled from 1960 hrough 1962, a density of 25 larvae per 100 twigs vas found in 1960. Then, in 1961 and 1962, *A. loverana* was not recovered at this plot. It was found t a very low density in one of three other plots ampled in 1961 and on grand fir in a paired plot n 1962.

Both species of *Zeiraphera* were recorded at moderate densities in 1960, ranging from 23 to 45 per 100 twigs at two Douglas-fir plots and from 95 to 118 per 100 twigs at two grand fir plots. In 1961 on Douglas-fir, *Z. hesperiana* showed little change. At the grand fir plot sampled for 3 years, the unidentified species of *Zeiraphera* dropped from 95 larvae per 100 twigs to 5 in 1961 and was recorded at 13 per 100 twigs in 1962. It was not recorded at the paired plot in 1962.

Southern Oregon. – In both subareas, the larval densities of most associated Lepidoptera showed strong reductions from 1960 to 1961 (table 5, appendix). In the north Warner Mountains, plots resampled in 1961 showed sharp reductions in the density of *Dioryctria reniculelloides,* the most abundant associate in 1960. In the Gearhart Mountains, plots resampled in 1961 showed a persistence of *Acleris gloverana* at a low level, a small reduction in *D. reniculelloides,* and a slight increase in a species of *Acantholyda.* At the one plot resampled in this subarea in 1962, there was no change in the density of *Acleris,* a further reduction in *Dioryctria,* a further increase in *Acantholyda,* and a small eruption of *Pleroneura* species.

Host Preference

NORTHEAST OREGON

At the Halfway plot, with larvae per 100 twigs used as a measure of density, the paired tree comparison showed the following: (1) no preference between Douglas-fir and grand fir by *Argyrotaenia dorsalana* and *Dioryctria reniculelloides*; (2) a strong preference for Douglas-fir by *Griselda radicana* and *Zeiraphera hesperiana*; (3) a strong preference for grand fir by *Acleris gloverana, Chionodes-Telphusa* spp., and *Zeiraphera* species. With larvae per 1,000 opening buds used as a measure of density, the same pattern was shown except that the preferences of *A. gloverana* and *Zeiraphera* sp. for grand fir were of less intensity.

The subdued ratings resulted from the contrasting number of new shoots per twig on the two tree species, averaging 19.7 on Douglas-fir, and 45.7 on grand fir. The presence of *Zeiraphera* sp. on the Douglas-fir trees was unusual and probably caused by wind-drift of small larvae from the grand fir trees. Larval densities were as follows:

Insect species	Douglas-fir	Grand fir	Douglas-fir	Grand fir
	- Per 100 twigs -		*- Per 1,000 buds -*	
Acleris gloverana	60	163	30	36
Argyrotaenia dorsalana	7	7	4	2
Chionodes-Telphusa spp.	0	22	0	5
Dioryctria reniculelloides	9	8	5	2
Griselda radicana	85	7	43	2
Zeiraphera hesperiana	48	2	25	1
Zeiraphera sp.	11	68	6	15

Information obtained during the follow-up, when almost half of the spruce budworm population had pupated, was limited to three associates. The *Zeiraphera* larvae had long since left the trees to pupate in the litter; and the *Argyrotaenia* larvae had also pupated, presumably on the trees, but were not found on the twig samples. *Dioryctria reniculelloides* was evident at a very low density on grand fir and was not found on Douglas-fir. *Griselda radicana* was three times as numerous on Douglas-fir as on grand fir, and *Acleris gloverana* and the species of *Chionodes-Telphusa* were found at much higher densities on grand fir.

EASTERN WASHINGTON CASCADES

Excluding colonies of *Neodiprion* sp. found only on the new shoots of Douglas-fir, only eight species of associated defoliators were found during the sampling of the paired trees. Most were represented by only one or two specimens on the 20 twigs cut per tree species. The only clear preference shown was by one or more species in the *Chionodes-Telphusa* complex. Larval density was 30 per 100 twigs on grand fir; no larvae were found on Douglas-fir.

This particular year, 1962, appeared to be the culmination of a decline in associated defoliators in this area; however, the western spruce budworm, of main interest in the test (Carolin and Coulter 1975), was on a steady upward trend (table 6, appendix).

Discussion

In studies based on sampling foliage for a particula insect, the number of other species occurring in immature stages poses a problem in recognition Especially with Lepidoptera, the coloration and markings of most larvae of the various species cha drastically from the time they are in the opening b until they are full-grown larvae. The early instars a a problem because their small size makes it difficu to see important morphological features. A hand l must be used frequently, and rearing is essential cases of doubt. Insects being reared should be re-checked under a microscope for features that ma have been overlooked with a hand lens. A key to sm larvae associated with spruce budworms in openi buds and new shoots is now available (Carolin an Stevens 1979).

The listing of budworm associates by tree species suggests that a few associates are restricted to one two tree species. It also indicates a different frequency of occurrence of some associates on differe tree species. The limited tests on host preference show that, even when frequency is the same, larv density of some associates may be greater on one t species than another. Thus, if associated defoliat are the subject of specific studies (i.e., finding alte nate hosts of budworm parasites; obtaining materia for taxonomic study), information on frequency occurrence and density on particular hosts is of par ticular value.

Examination of trends of associated species durin 1955-59 suggests a strong climatic influence at wor between 1956 and 1957, facilitating the strong u ward surge, in both sprayed and unsprayed areas, o nearly all associated defoliators along with the western spruce budworm. One must assume that favorable conditions for both survival and reproduc tion occurred from summer of 1956 through spring of 1957. Less favorable conditions then occurred in 1957-58 and in 1958-59. Slight differences in years of peaking, followed by a decline, might be due to the influence of geographic location; but without local meteorological data, this could not be proven.

Conclusions

ends shown by major associates were remarkably
nsistent between areas in some cases, and no more
riable than one might expect in other cases. *Dio-
ctria reniculelloides* peaked in all sprayed and
isprayed areas in 1957, then declined sharply. In
rtheast Oregon *Zeiraphera hesperiana* peaked in
th sprayed and unsprayed areas in 1957. In sprayed
eas, *Griselda radicana* peaked in 1957, with lower
aks in northeast Oregon; in unsprayed areas in
rtheast Oregon, it peaked either in 1957 or 1958.
cleris gloverana, an insect which is more at home in
rthwestern Oregon and western Washington,
aked later than the other associates by a year or
o in all areas. Subsequent studies in eastern Wash-
gton indicate a collapse of *A. gloverana* in 1960.

ends in the Eugene area (the western foothills of
e Cascades in west-central Oregon) were slightly
fferent for some associates. Peaks for *Zeiraphera
speriana, Coleotechnites* near *piceaella,* and
rgyotaenia dorsalana were all in 1958, a year later
an in most other areas. One might expect some
fferences in this area from geographic moderation
climatic influences.

ie apparent downward trend of lepidopterous asso-
ates in the eastern Washington Cascades during
960-62 may represent a continuation of the general
end shown in northeast Oregon. The lack of sam-
ing data for unsprayed conditions in both areas in
959 eliminates the basis for a conclusion. On the
her hand, southern Oregon probably represents a
fferent universe.

ie similarity in trends between sprayed and un-
rayed areas after 1954 might seem to indicate that
e effects of the 1949 and 1950 spraying had largely
ssipated; however during 1955-59 (tables 4, 6, ap-
endix), densities of the common associates, with the
ception of *Coleotechnites* near *piceaella,* were
bstantially higher in the unsprayed areas.

mixed fir types, the selection of Douglas-fir over
and or white fir as a standard tree species for sam-
ing western spruce budworm is advantageous in
etermining trends of its associates. In unsprayed
eas, the greater susceptibility of grand and white fir
bud-killing (Carolin and Coulter 1975) results in a
duction of the food supply; this sets up a competi-
ve situation between the budworm and its associates
id between associates. Trends could be determined
ir categories of tree damage, but would require a
ibstantially stepped-up sampling effort.

The larvae of a number of defoliators feed in association with spruce budworms in opening buds and new shoots of Douglas-fir, grand fir, and white fir. In Oregon and Washington, about 20 species that are common, occasional, or sporadic on one or more of these hosts should be recognized during sampling for spruce budworms.

Trends of major associates can be determined by recording their numbers during sampling at fixed plots for spruce budworms at the larvae-in-opening-buds stage. Observers should learn to recognize larvae of the most common species in their study areas and should rear any species of uncertain identity.

Strong oscillations in the densities of the various associates appear to be controlled by the same major factor or set of factors that control densities of spruce budworms in these same areas. If so, annual sampling of host trees for associates, in stands away from typical spruce budworm outbreak areas, could have considerable value in predicting trends of spruce budworms.

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pendix

e 4 — Comparison of average larval densities of western spruce budworm and associated defoliators in on and Washington infestations (In number of larvae per one hundred 15-inch twigs)

y area and tree species	1951	1952	1953	1954	1955	1956	1957	1958	1959
SPRAYED AREAS									
ne — Douglas-fir:									
estern spruce budworm	0.3	2	8	24	6	7	16	13	7
sociated defoliators	31	49	12	4	45	55	98	63	33.5
nt Hood — Douglas-fir:									
estern spruce budworm	13	28	1	0	7	6	15	12.5	0.5
sociated defoliators	5.5	13.5	7.5	1.5	4	15.5	21	40	33
n Umatilla — Douglas-fir:									
estern spruce budworm	4.5	0.5	5	10	17.5	11	19	7	6.5
sociated defoliators	9.5	15.5	1.5	1.5	11	25	43	38	26
rande — Douglas-fir:									
estern spruce budworm	20	26	24	16.5	39	12.5	14	8.5	6
sociated defoliators	3.5	14.5	9	0	73	69.5	102.5	54.5	16
n Umatilla — subalpine fir:									
estern spruce budworm	5	4	0	0	2.5	2.5	4.5	0.5	1
sociated defoliators	1	6	4	3	6.5	11	34	78.5	69

e 5 — Comparison of average larval densities of Modoc budworm and associated defoliators in hern Oregon infestations (In number of larvae per one hundred 15-inch twigs)

ly area and tree species	1959	1960	1961	1962
th Warner Mountains — white fir:				
odoc budworm	—	1322	401	—
ssociated defoliators	—	174	26	—
hart Mountains — white fir:				
odoc budworm	—	621	236	110
ssociated defoliators	—	95	60	127

Table 6 — Comparison of average larval densities of western spruce budworm and associated defoliators in Oregon and Washington infestations (In number of larvae per one hundred 15-inch twigs)

Study area and tree species	1955	1956	1957	1958	1959	1960	1961
UNSPRAYED AREAS, N. E. OREGON							
Baker — Douglas-fir:							
Western spruce budworm	281	227	597	310	—	—	—
Associated defoliators	53	92	215	105	—	—	—
Chesnimnus — Douglas-fir:							
Western spruce budworm	177	190	141	—	—	—	—
Associated defoliators	7	40	147	—	—	—	—
Dale — Douglas-fir:							
Western spruce budworm	851	1700	2186	324	—	—	—
Associated defoliators	123	149	490	208	—	—	—
Dixie — Douglas-fir:[1]							
Western spruce budworm	—	—	1010	385	—	—	—
Associated defoliators	—	—	13	26	—	—	—
Joseph — Douglas-fir:							
Western spruce budworm	309	224	433	224	88	—	—
Associated defoliators	13	43	152	166	122	—	—
UNSPRAYED AREAS, E. WASHINGTON							
Goldendale — Douglas-fir:							
Western spruce budworm	—	—	—	—	—	365	428
Associated defoliators	—	—	—	—	—	51	46
Goldendale — grand fir:							
Western spruce budworm	—	—	—	—	—	215	1206
Associated defoliators	—	—	—	—	—	151	29

[1] Trees with severe damage.

Carolin, V. M.
1980. Larval densities and trends of insect species associated with spruce budworms in buds and shoots in Oregon and Washington. USDA For. Serv. Res. Pap. PNW-273, 18 p. Pac. Northwest For. and Range Exp. Station, Portland, Oregon.

Sampling studies on western spruce budworm and Modoc budworm disclosed a substantial number of associated insect species at the time larvae were in opening buds. About 20 species occur with sufficient regularity to justify identification by field crews.

Keywords: Insect populations, reproductive behavior (insect), western spruce budworm, identification (insect), *Choristoneura occidentalis*, Modoc budworm, *Choristoneura viridis*.

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Pacific Northwest
Forest and Range
Experiment Station

Research Paper
PNW-274

June 1980

Green Fescue Grassland: 40 Years of Secondary Succession

Elbert H. Reid, Gerald S. Strickler, and Wade B. Hall

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Metric Equivalents

1 foot = 0.3048 meter
1 inch = 2.54 centimeters
1 acre = 0.4047 hectare
1 square foot = 0.0929 square meter

reen Fescue Grassland: 40 Years
f Secondary Succession

ference Abstract

d, Elbert H., Gerald S. Strickler, and
e B. Hall.
80. Green fescue grassland: 40 years
f secondary succession. USDA For.
erv. Res. Pap. PNW-274, 39 p. Pacific
orthwest Forest and Range Experiment
tation, Portland, Oregon.

40-year succession of a depleted
en fescue (Festuca viridula) subalpine
ssland in the Wallowa Mountains,
gon, was influenced by historic soil
sion. Range conditions of the grass-
d annually grazed by domestic sheep
roved greatly between 1938 and 1978;
t of the improvement occurred between
30th and 40th years. Photographs
ustrate the changes.

words: Grassland management,
cession, fescue, Festuca, grazing
nge), subalpine grasslands.

Research Summary
Research Paper PNW-274
1980

A green fescue (Festuca viridula Vas.) subalpine grassland in northeastern Oregon, heavily grazed by sheep for 50 years, was in poor condition when first studied in 1938. Accelerated erosion was evident and much topsoil (6-10 inches) had been lost. Green fescue had been replaced by needlegrass, sedges, and several forbs where erosion had removed all topsoil. On less eroded sites, some topsoil remained in pedestals of sod held in place by masses of dead fescue roots. A few pedestals supported small, weakened fescue plants. Others supported needlegrass, sedges, and deep-rooted forbs, such as Nuttall linanthastrum and fleeceflower. A large percentage of pedestals and the eroded surface between them had no plant growth. Photographs illustrated the conditions.

Improvement of both land- and sheep-management practices after 1938 initiated secondary succession that was measured and photographed again in 1956, 1968, and 1978.

Continued accelerated erosion was not evident in 1956, nor in 1968 and 1978.

After 18 years (1956), green fescue had reestablished where topsoil remained; vegetation density, cover, and production had increased, particularly that of needlegrass, sedges, and Nuttall linanthastrum; and plant vigor had greatly improved. Past erosion had greatly regulated the degree of recovery on individual sites. Needlegrass was conspicuous on eroded surfaces.

At 30 years (1968), density and cover of vegetation had increased, primarily from increases in density of several grasses and sedges on the eroded surfaces. Cover and density of some forbs had declined. Needlegrass was still the dominant grass, although density of green fescue had continued to improve on the deeper soils.

At 40 years (1978), green fescue had become the dominant grass; the density of needlegrass, sedges, and most forbs had decreased on the less eroded soils; and green fescue was as prominent as other species on most eroded surfaces.

It was concluded that the present vegetation on many sites will prevail in the future because of past erosion, but that green fescue density should continue to increase, under good management practices, where sufficient topsoil remains.

roduction

een fecue (*Festuca viridula* Vas.)[1/]
lpine grassland in the Wallowa Moun-
ns of northeast Oregon was studied in-
ively in 1938 (Pickford and Reid
). The area had been heavily grazed
heep for 50 years and was in poor con-
on. Photographs recorded the deter-
ted vegetation and accelerated soil
sion sampled on the study plots.

paper summarizes the changes in vege-
on and soil erosion that occurred
improved management and illustrates,
photographs, 18, 30, and 40 years of
ndary succession on the grassland.

---

lant nomenclature follows Hitchcock
Cronquist (1973).

The Study Area

The 690-acre study area is located on southerly slopes between 7,200 and 8,500 feet in Tenderfoot Basin near the headwaters of the North Fork of the Imnaha River. The vegetation is typical of much of the subalpine fir (*Abies lasiocarpa* (Hook) Nutt.) zone--large expanses of grassland interspersed by groups of or individual subalpine fir and whitebark pine (*Pinus albicaulis* Engelm.) (fig. 1).

The underlying rock is primarily limestone and basalt with some shaly and slaty beds (Baldwin 1964, Smith and Allen 1941). Soils are strongly influenced by loess and vary in depth and texture. They are shallow and very stony on ridgetops and around outcrops. On slopes and in drainage basins, soils are 2 to 3 feet or more in depth, silt loam in texture, and generally weakly structured. Without a protective cover of vegetation they are easily eroded by water and wind.

Annual precipitation is between 40 and 50 inches; most occurs as fall rain and winter snow. Snowmelt is usually complete on southerly slopes by July 1. Summer storms account for 10 to 20 percent of the annual precipitation. Growth of vegetation is rapid, peaking near mid-August, and seed dissemination by green fescue occurs about September 1 (Sampson 1914).

Procedures

In 1938, soil erosion classes and estimates of plant species cover and composition, by the square-foot density method (Stewart and Hutchings 1936), were determined from plots gridding the study area at $3\frac{1}{2}$-chain intervals. Photographs were taken to illustrate data obtained on the plots. These methods were repeated between 1956 and 1960, allowing both quantitative and qualitative discussion of 18-year successional trends (Strickler 1961).

The photo sites were photographed again in 1968 and 1978, and changes in plant composition and soil erosion were noted. Resampling the plots in 1968 and 1978 would have provided continuity of the quantitative aspects of the study, but time was not available for this work. Therefore, the 1968 objectives (repeated in 1978) were to: (1) rephotograph the sites reestablished in 1956, 1957, and 1960; (2) estimate, by the square-foot density method, species cover and composition illustrated in the photographs; and (3) make onsite qualitative comparisons of soil and vegetation characteristics with those in the previous photographs and descriptive record. Reid, who did the original 1938 study and assisted in photographing the sites in 1956, and Hall, who also assisted in the 1956 study, did the work. Because of this, the qualitative assessment of the 30- and 40-year changes could be maintained, and a quantitative record of cover and composition of the photographed vegetation was available for the 1968-78 period.

Unfortunately, sheep had grazed the study area 2 days before the 1968 photographs were taken, and only a few sites were ungrazed. In addition, heavy snows on the 1st day of study in both 1968 and 1978 compressed herbage growth to the surface. In 1968, these conditions prevented cover estimates on most sites and allowed only poor comparisons of vegetation and soil characteristics with earlier or later photographs; only three of the 1968 photographs are used. Most sites were snow free, however, when the photographs were taken in 1978, so normal vegetation growth is shown. Where grazing (1968) and snow (1968 and 1978) prevented accurate estimates of cover, relative abundance of species in the photographed area was noted to assess change from similar qualitative descriptions recorded in 1956.

After the 1978 field work, the four photographs and accompanying data from each o 34 photographed sites were examined for changes in vegetation and soil erosion relative to: (1) the 1938 soil erosion class recorded with or observed in the original photograph; (2) the specific habitat, such as swale, slope, or ridge; and (3) the estimated soil depth and moisture characteristics. Discussion of plant successional trends is based on these assessments.

A 5x7 (negative size in inches) camera was used in the 1938 photography, whereas a 4x5 camera was used in subsequent years. Enlarging 4x5 negatives to match the original prints resulted in slight differences in the area covered. Wet soils in the 1968 and 1978 photographs have tones that are similar to the vegetation; and this made it difficult to compare the extent of barren soil with that in earlier photographs. We therefore determined these changes from color positive images taken in 1956, 1968, and 1978 Figures 1-10 (pages 12-37) illustrate the variation in trends.

Work in all years was done in August when the green standing crop had peaked.

e by Sheep Before 1938

openness and productivity of green fes-
grassland make them prime summer range
domestic sheep (Ovis aries). In the
lowa Mountains, sheep began grazing the
sslands in the early 1880's, and their
bers quickly increased (Wentworth 1948).

ly use of the study area is not well
umented, but some records indicate
derfoot Basin was badly overgrazed and
eriorated by 1900. For example, a
y 15, 1903, photograph, from the adja-
t Aneroid Basin, shows a wide expanse
green fescue grassland with no visible
bage growth. The photographer noted:
ass almost destroyed by early graz-
. Snow hardly gone but sheep have run
r hills through mud."2/

1938, the 2,256 acres of the upper
derfoot Basin allotment had an esti-
ed grazing capacity of 0.44 sheep
th (SM)/acre (Pickford and Reid 1942).
s estimate closely approximated the
ual use of the study area in 1938 when
ep removed 44 percent of the green fes-
herbage, slightly below the 50 percent
sidered proper use. This grazing
acity, however, was apparently a great
uction from earlier capacity. In
6, four 1,200-head bands of sheep were
orted to have grazed the allotment, in-
ding the study area, for 3 months, a
cking equal to 6.4 SM/acre or 15 times
e capacity than the area could support
1938. The reduction in capacity was
o compared in 1938 with that of an
acent (Lick Creek), uneroded, lightly
zed, near-climax green fescue range.
estimated capacity was 5.35 SM/acre
12 times more than the deteriorated
ge in Tenderfoot Basin (Pickford and
d 1942).

---

hotograph files, Range and Wildlife
itat Laboratory, Pacific Northwest
est and Range Experiment Station, La
nde, Oregon.

Use by Sheep, 1938 to 1978

Use of the allotment and study area from 1938 to 1945 by sheep was the same as in 1938; 0.44 SM/acre. No sheep grazed the study area between 1945 and 1948. Grazing use was further reduced in 1949, and grazing was usually deferred until late August or early September in the study area. Except for the years 1953 and 1972 when there was no use, the upper Tenderfoot Basin averaged 0.17 SM/acre from 1949 through 1978. These records indicate use of the study area by sheep for the last 30 years was 60 percent less than the 1938 estimated capacity and only 3 percent of the capacity of a climax vegetation.

Soil and Vegetation in 1938

Measurements in 1938 showed that large amounts of topsoil had been lost through erosion and that the remaining vegetation was in poor condition (Pickford and Reid 1942). The degree of soil erosion varied by site, depending on soil depth, slope, amount of trailing by the sheep, proximity to the bedgrounds, or its use as a permanent bedground. The site, kind of grazing, and degree of erosion influenced the type of vegetation present.

One site was considered to be in near-climax condition (fig. 2). Green fescue accounted for 80-90 percent of the vegetation, and erosion was minimal. The fescue root mass was concentrated in a dense sod, 6 to 10 inches in depth.

Severe erosion had cut the fescue sod in other sites, and there remained only remnant soil pedestals or miniature mesalike hummocks. Much of the fescue was dead, but the sod remnants were held firmly in place by the persistent dead root masses (fig. 3). Open stands of Letterman needlegrass (*Stipa lettermanii* Vas.), a minor secondary species in climax vegetation, were conspicuous under these erosion conditions (fig. 4).

Where annual sheep trailing was intensive on the slopes, the sod had been cut, giving a stairstep appearance. Although a few pedestals supported low-vigor fescue, most had been invaded by needlegrass, sedges (*Carex* spp.), and perennial forbs, such as Nuttall linanthastrum (*Linanthastrum nuttallii* (Gray) Ewan.), cinquefoils (*Potentilla* spp.), lambstongue groundsel (*Senecio integerrimus* Nutt.), western yarrow (*Achillea millefolium* var. *lanulosa* Piper), and Rydberg penstemon (*Penstemon rydbergi* A. Nels.). Perennial forbs dominated in some areas (figs. 5 and 6) and needlegrass in others (fig. 7).

Erosion had progressed farther near bedgrounds and on intensively trailed areas; only a few sod pedestals remained on an extensively eroded surface that was covered with an erosion pavement of small stones and gravel. Pedestals were occupied by forbs or needlegrass (fig. 8), but where grazing was not heavy, fescue usually capped them. The eroded surfaces were either barren or occupied by needlegrass.

Perennial forbs commonly occupied areas where all topsoil sod had been eroded away. Where the remaining soil was deep or moist, the sites were usually occupie by penstemon, groundsel, fleabane (*Erigeron* spp.), and Nuttall linanthastrum in combination with needlegrass and sedges, principally ovalhead sedge (*Care festivella* Mack.) (fig. 9). Eriogonum (either or both Wyeth eriogonum (*Eriogon herocleoides* Nutt.) and Piper eriogonum (*Eriogonum flavum* Nutt.)) was the domina forb on drier sites, especially those wi shallow soils (fig. 10).

esults

he First 18 Years: 1938-56

en with continued sheep use, no further
jor loss of soil was observed in 1956.
st soil pedestals present in 1938 were
ill intact (fig. 3) and generally sup-
rted a vigorous growth of perennial
ants. Soil sloughing from the pedestals
d remained on the eroded surface and
s stabilized by encroaching plants. The
d erosion channels, the extensive pave-
nts on old bedgrounds, and stock trails
re also healing with the invasion of
ants. Density, cover, and production
d increased, particularly that of
edlegrass, green fescue, linanthastrum,
d sedges.

ss of topsoil and the encroachment and
crease of secondary species prior to
38 had the greatest effect in preventing
substantial improvement in vegetation
1956. These factors appeared to regu-
te the rate of plant establishment and
creases in density, cover, and produc-
on of plants, especially green fescue,
though vigor of fescue had greatly im-
oved on all sites. It was concluded
at plant density was approaching its
tential on the eroded sites and that
ny secondary and associated species
uld maintain their prominence in future
ars (Strickler 1961).

Eighteen to Thirty Years: 1956-68

The major change in the vegetation during this 12-year period was an increase in density and cover of grasses, particularly needlegrass and green fescue, and some decrease in perennial forb cover.

The aspect was of a grass-forb mixture or of a grass sward in areas where topsoil remained in pedestals. Grasses and sedges had thickened on the erosion pavements where they had occurred as sparse stands in 1956, or they had continued to spread, reducing the extent of bare areas. The principal species thickening or spreading were needlegrass, ovalhead sedge, and green fescue. In some areas, California brome (*Bromus carinatus* H. & A.), bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) J. G. Sm.), and oniongrass (*Melica bulbosa* Geyer ex Porter & Coult.) were the main species. Cutting wheatgrass (*Agropyron caninum* (L.) Beauv.) occurred as occasional plants.

As in 1956, further accelerated erosion of the soil was not evident. A few soil pedestals, recognizable from the earlier photographs, had fallen over. Some had rolled downslope.

Thirty to Forty Years: 1968-78

Between the 30th and 40th year, there was a general reduction in density of needlegrass, sedge, and perennial forbs, a large increase in density of green fescue, and a continued increase in total plant cover.

By 1978, needlegrass had become a secondary constituent of the vegetation in some areas where it previously had dominated, and had become very sparse or was no longer found on other sites. Green fescue had become the dominant grass. The grasses and sedges had continued to invade on bare areas, and green fescue was as much of an invader as were needlegrass and sedge.

Perennial forbs were still prominent in the vegetation. Forb composition was g erally the same as in 1938, but density and cover were less. The continued lon gevity of forbs, noted in 1956, was unexpected. Plants of fleeceflower (Poly gonum phytolaccaefolium Meism. ex Small Nuttall linanthastrum, Rydberg penstemo and the eriogonums seen in some 1938 photographs were still present in 1978. The fleeceflower continued to increase some areas in spite of the fact that th plant is quite palatable to sheep. The other long-lived forbs are less palatab yet they decreased in density.

Again, accelerated erosion of the soil was not apparent. Many soil pedestals observed in 1968 (the same ones as in 1938) were still in evidence in 1978 an were of similar shape and size. Most were more rounded, however, and, being well vegetated, not as conspicuous as i 1968. The slopes still had a stairstep appearance, but the steps were less abr and litter covered much of the interven spaces.

here green fescue formed dense stands on
neroded soil in 1938, the same situation
xisted 40 years later. Thus, Clements'
1916) and Pickford and Reid's (1942) con-
epts are verified; namely, that a sub-
lpine grassland climax is one in which
he climax grass species occurs in an al-
ost pure stand. Any severe use by sheep
ould reduce palatable climax species and
llow secondary species to increase, as
as observed in 1944 on one site (fig. 2).
ssentially uneroded, this site required
t least 20 years to recover and to ap-
roximate the original climax composition.

here less residual topsoil remained and
reen fescue was badly depleted or elimi-
ated, secondary succession was slower
nd generally proceeded from a perennial
orb and/or needlegrass community to one
ominated by needlegrass and sedge, then
o replacement of the needlegrass, sedge,
nd some forbs by green fescue. The rate
nd extent of succession on eroded sites,
owever, varied with depth of remaining
opsoil, soil moisture relations, and
pecies present in 1938.

The eriogonums, particularly Wyeth eriogonum, were the dominant species on the thin soils and erosion pavement of eroded sites in 1938. Grasses were sparse, but needlegrass was the most abundant. By 1956, eriogonum had increased in density, and some penstemon had become established. Needlegrass was still dominant but had not increased greatly. In 1978, after 40 years, eriogonum was still the dominant species, but the needlegrass had been mainly replaced by green fescue.

Moist, yet well-drained sites with shallow topsoil residues were generally occupied by fleabanes, eriogonums, groundsel, sedges, and needlegrass in 1938. Forbs predominated, sedges were secondary, and needlegrass was relatively minor. All forbs had decreased somewhat after 18 years but were still prominent. Needlegrass and sedges had increased greatly, up to half the vegetation cover. There was a general thickening of needlegrass and sedge within 30 years, but there appeared to be no general change in forbs. Some green fescue, about 5 percent of the cover, was apparent. Green fescue was the predominant species at 40 years. Sedge and some forbs, primarily fleabane and eriogonum, remained, but needlegrass had essentially disappeared.

Several successional patterns occurred on well-drained sites where good topsoil remained. On sites where the original green fescue had died out but the root masses were still largely intact, dense stands of forbs, needlegrass, and sedge were well established in 1938. Nuttall linanthastrum and fleeceflower were prominent. Green fescue was prominent after 18 years. By 1968, after 30 years, little change was observed. After 40 years, however, green fescue had greatly increased in density and was the dominant plant. It had largely replaced needlegrass and sedge. Fescue accounted for about half the plant cover, Nuttall linanthastrum about 25 percent, and penstemon 10 percent.

On similar sites where, in 1938, small tufts of green fescue remained and were growing among plants of needlegrass and sedges on topsoil pedestals, the fescue had gained vigor by 1956 but had not increased materially in density. Needlegrass and sedge had thickened and become the dominant species, making a rather dense sward. Much the same situation existed 30 years later. At 40 years, these areas supported a dense stand of green fescue with only minor amounts of needlegrass and sedges. Forbs had not been involved in this succession.

Less well-drained sites, with good amounts of topsoil, were mainly occupied by forbs in 1938, although some green fescue, needlegrass, sedge, and other grasses were found. Major forb species--penstemon, cinquefoil, fleeceflower, stickseed, and eriogonums--varied from site to site. By 1956, needlegrass and sedge had greatly increased, but forbs were still dominant. Much the same situation existed after 30 years, although needlegrass and sedge had again greatly increased. Green fescue had become the dominant species at 40 years, yet forbs were still prominent. The two most notable changes between the 30th and 40t year were the marked increase in total cover and the replacement of needlegrass and sedge by green fescue.

The observations of ecological changes over the 40-year period demonstrate the benefits of long-term studies to understand plant succession and the effects o good management practices on deteriorate ranges. We cannot readily explain, however, why the major changes in plant composition, particularly the marked increa in green fescue, occurred between the 30 and 40th years. One would have expected this to occur earlier than the 30th year where green fescue had recovered to a co dominant or dominant position in the veg tation, but not where the fescue was sti sparse and competing with dense cover of secondary species for the limited space, nutrients, and moisture of an eroded soi

Good seed production was observed in all remeasurement years on all sites, indicating that annual seed production was r the limiting factor. Assuming similar seed production for the intervening years, we suggest that certain physical and physiological requirements for survival and establishment of fescue seedlings, or expansion (tillering) of existing fescue plants, were not met in the early years because of the altered micro environment of the eroded soil (Ellison 1949, 1960).

e changes that occurred between the
th and 40th years may be closely asso-
ated with accumulation of organic mat-
r and the amelioration of the surface
vironment. These changes would have a
gnificant effect on available water,
trients, and other factors affecting
ant growth (Cundell 1977, Mooney et al.
65). Recent work on associations of
stuca species, from climax and advanced
ccessional communities, with mycor-
izal fungi (Molina et al. 1978) and
all mammal populations (Maser and
rickler 1978), and on the role of
corrhizal fungi on eroded or otherwise
sturbed ecosystems (Hall and Armstrong
79, Miller 1979, Reeves et al. 1979)
ggests that mycorrhiza infection levels
y have been a limiting factor for im-
oving growth of green fescue and sur-
val of seedlings until the 30th year of
ccession.

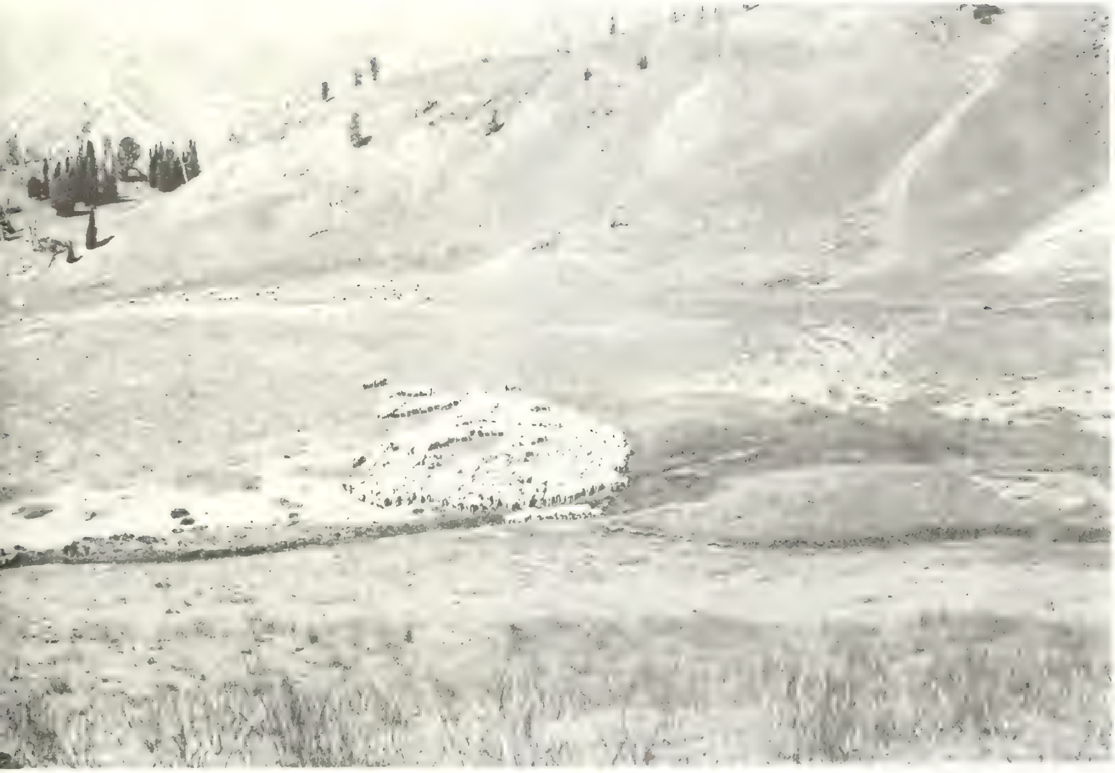
vertheless, we think that the reduction
sheep months of grazing and the defer-
nt practiced in the 40-year period were
e major factors in the improvement. In
s 40-year successional study of grazed
balpine herblands of the Wasatch
ateau, Utah, Ellison (1954) showed that
e upward trend, beginning in 1913 with
e initial great reduction in sheep num-
rs, had virtually ceased after 20 or
years and indicated that management
actices were still not adequate for
ntinuing improvement.

Figure 1

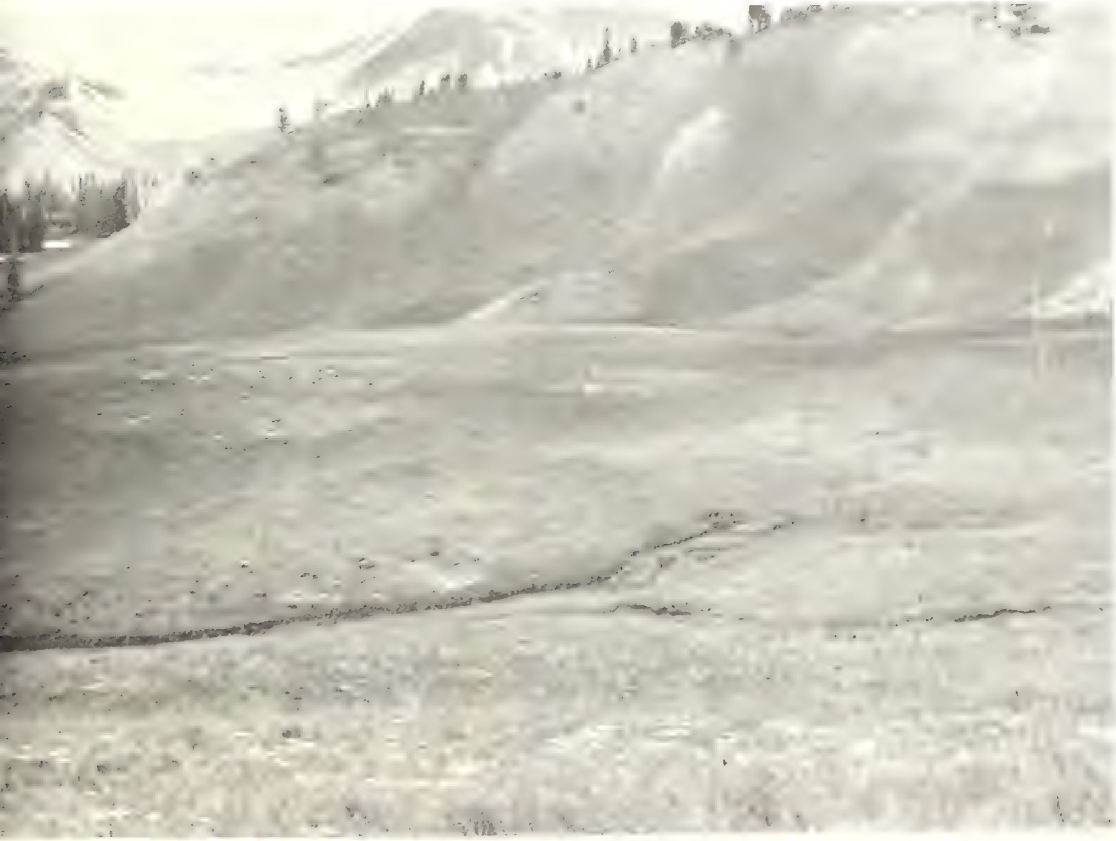
1938--sheep bunched on one of the main bedgrounds. Such concentration of sheep hastened depletion of vegetation and erosion of soil through heavy forage utilization and intensive trampling. The vegetation was in poor condition, and there were many barren areas. Letterman needlegrass was the dominant plant on the slope in the foreground.

Figure 1

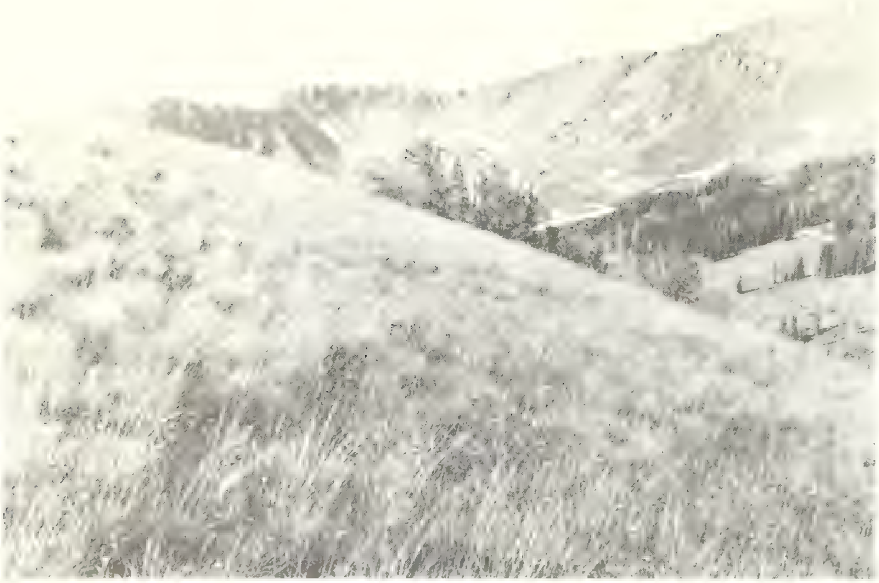
1978--40 years later, after the study area had been under reduced and deferred grazing, the condition of the range had greatly improved. Many bare areas had filled in with grass (fescue and needlegrass) and sedge. Green fescue was the dominant plant on the slope in the foreground. The white in the foreground is snow.



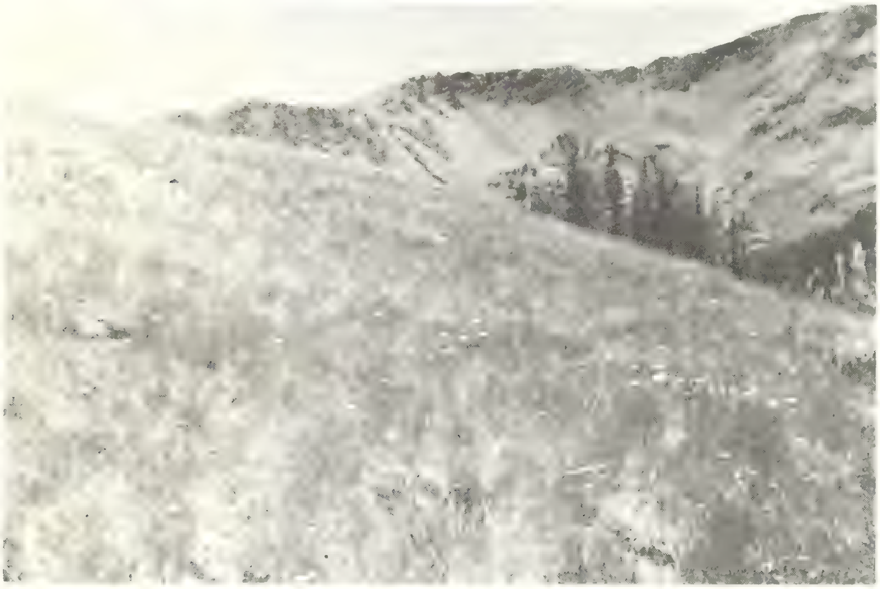
1938



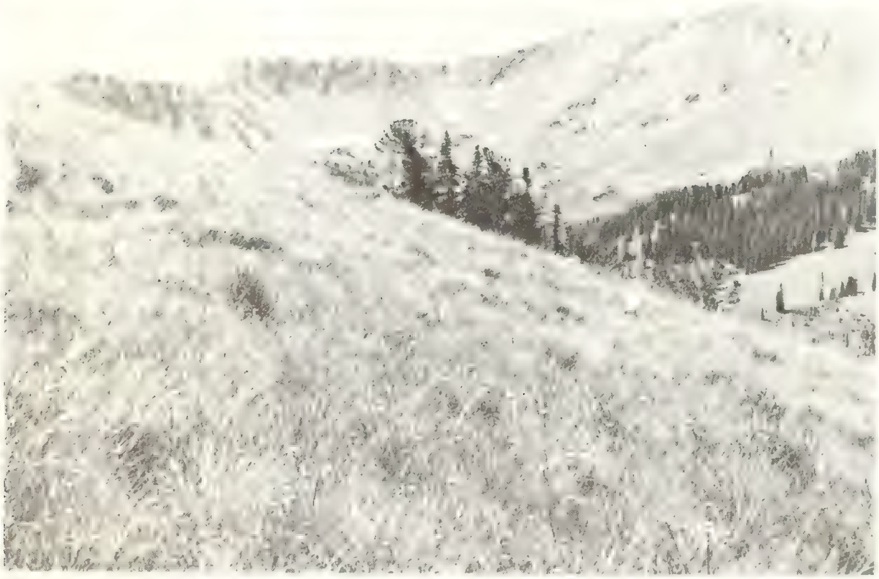
1978



1938



1944



1956

gure 2

*38--A subalpine grassland community in good condition. Vigorous green fescue was
e dominant species; only occasional plants of other grasses and forbs were present.*

gure 2

*44--condition of the community had deteriorated because of heavy use as a sheep bed-
ound for two consecutive seasons. Density and cover of green fescue had decreased
d that of needlegrass, yarrow, and fleabane had increased since 1938. Accelerated
il erosion, however, had not occurred.*

gure 2

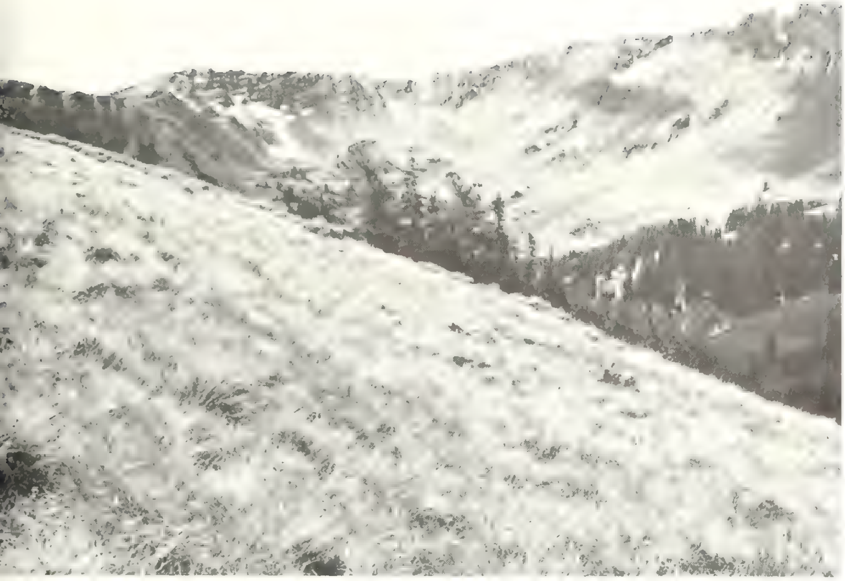
*56--green fescue was 58 percent, fleabane 22 percent, needlegrass and yarrow 6 percent
ch, and sedge 3 percent of the plant composition. Plant cover was much improved over
at of 1944.*

Figure 2 (continued)

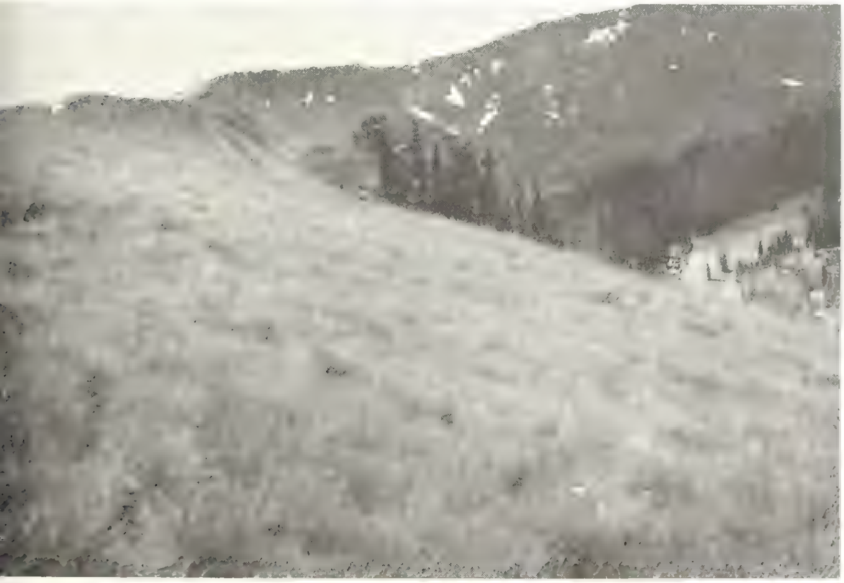
1968--vegetation cover and composition appeared much as it did in 1938, having recovere from the deteriorated condition in 1944.

Figure 2

1978--green fescue was 90 percent of the vegetation cover. Secondary species were western yarrow, ovalhead sedge, penstemon, and western needlegrass. Vegetation was again i good condition and approximated the climax community.



1968



1978

Figure 3

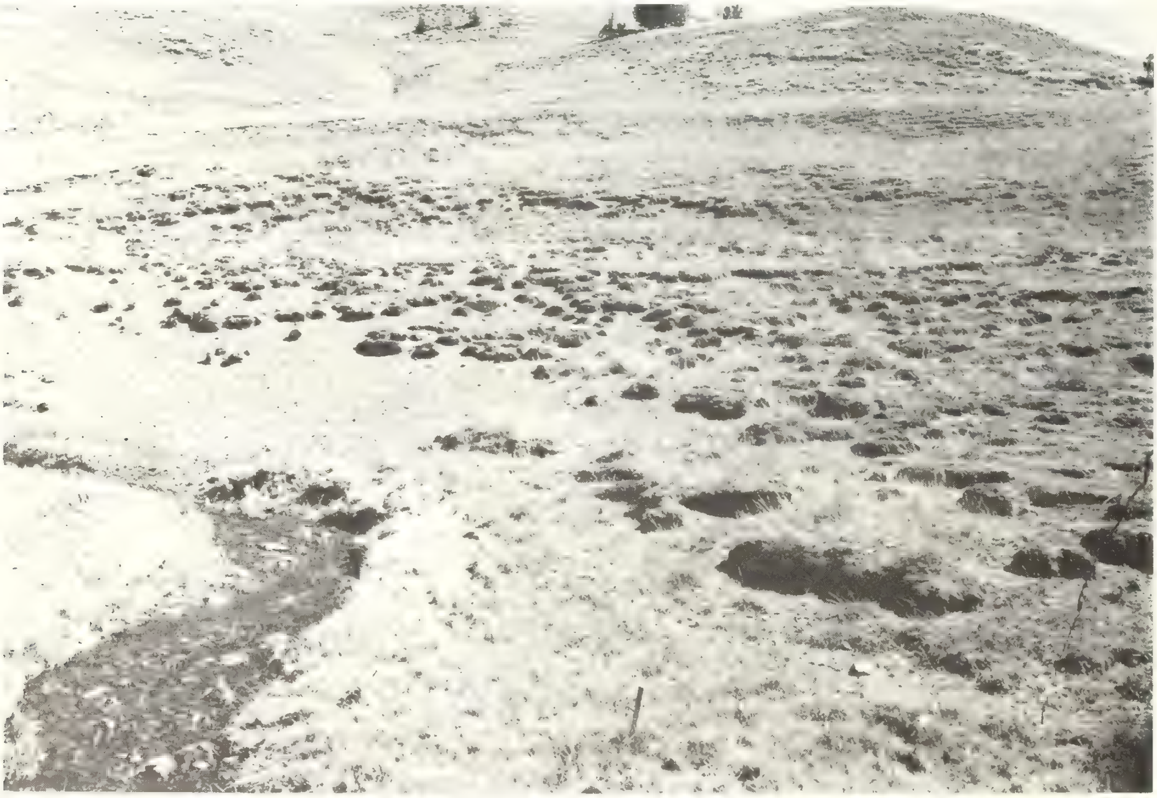
1938--an eroded slope near permanent water where much of the original topsoil was lost. Dead roots of green fescue held 80 percent of the foreground pedestals in place; live fescue and needlegrass occupied the remaining pedestals. Needlegrass was the dominant plant on the eroded surface between pedestals. Sedges occurred along the stream.

Figure 3

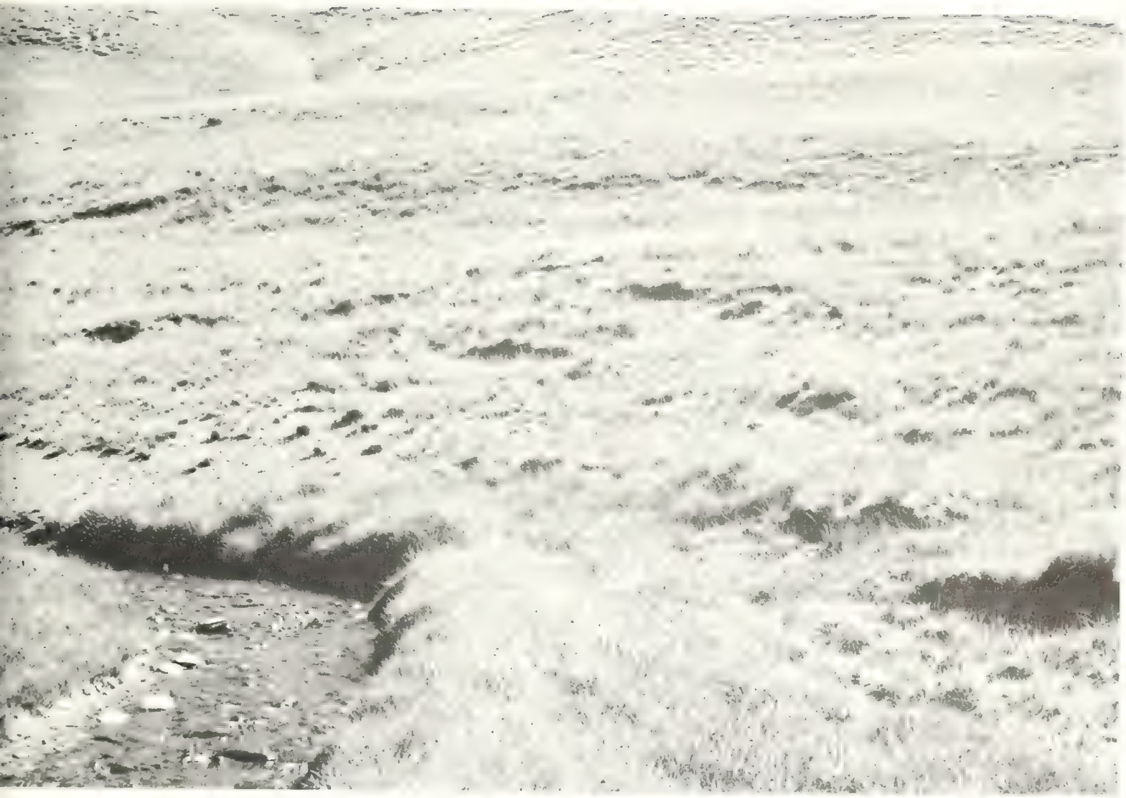
1956--cover had increased greatly; most was needlegrass that had increased on the erode surface, with some thickening of plants on the pedestals. Density and cover of green fescue had also increased. Note that most of the soil pedestals were still in place.

Figure 3

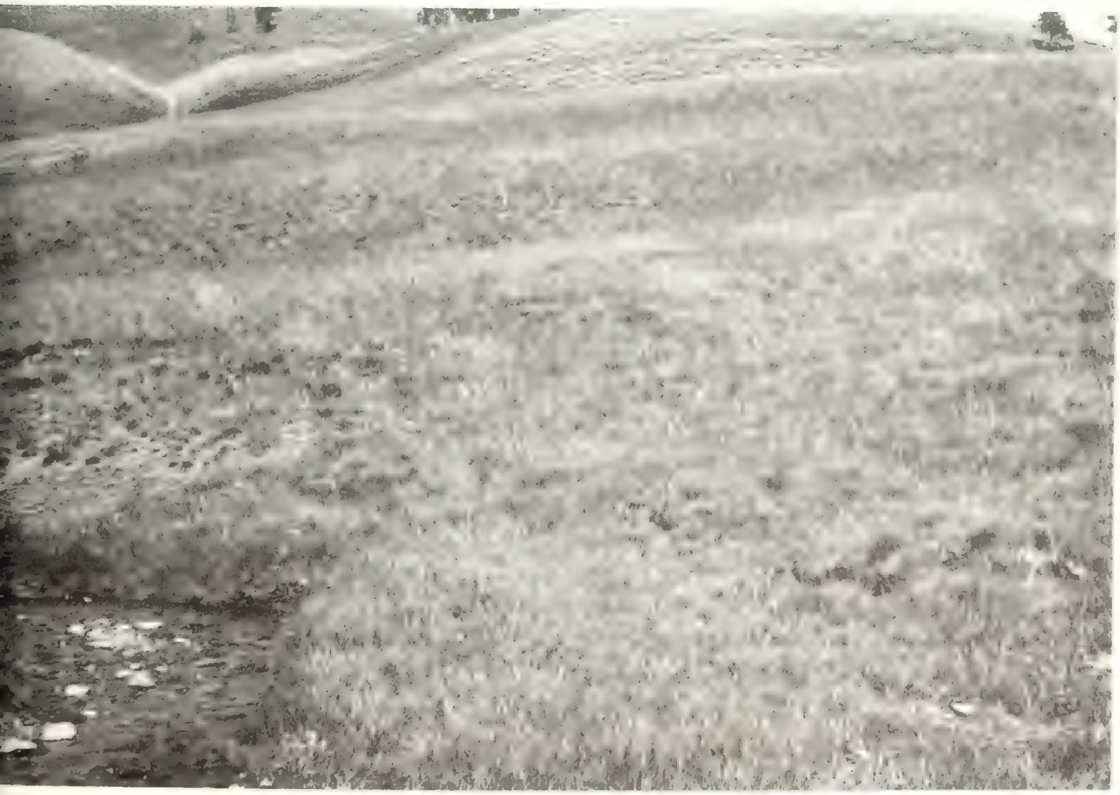
1978--vegetation cover on the slope continued to increase, both on and between the pedestals. A majority of the cover was green fescue, needlegrass, and sedges, with minor amounts of other grasses and forbs. Soil pedestals were still present, but the slope had lost some of its stairstep appearance. Green fescue had mainly replaced the needlegrass as the dominant species; most of this replacement took place between 1968 and 1978. Sedges and penstemon were the main species along the stream.



1938



1956



1978

Figure 4

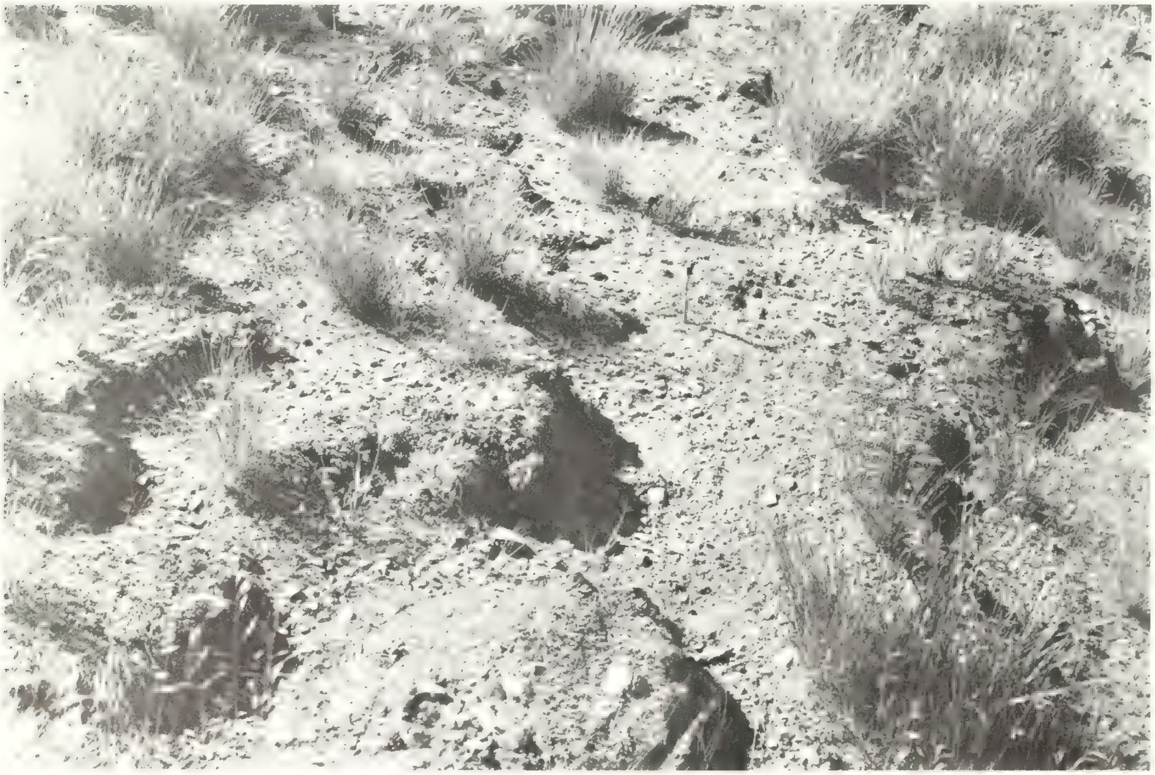
1938--a closeup of the condition on the slope shown in figure 3: The masses of dead green fescue roots hold the topsoil in place; remnant fescue plants of low vigor are widely scattered.

Figure 4

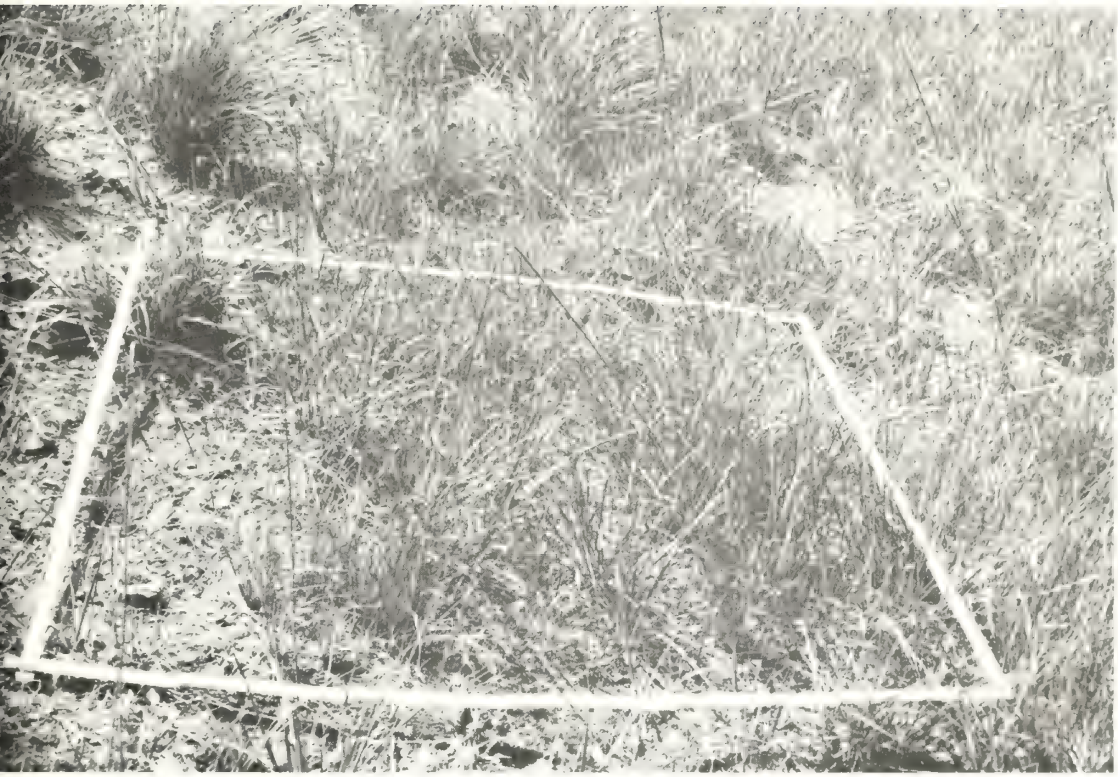
1956--18 years later, there had been a major increase in needlegrass; it was the domina species. Green fescue plants had increased greatly in vigor but not much in density. Litter had increased, and the soil pedestals, though still present, were not as prominent as in 1938.

Figure 4

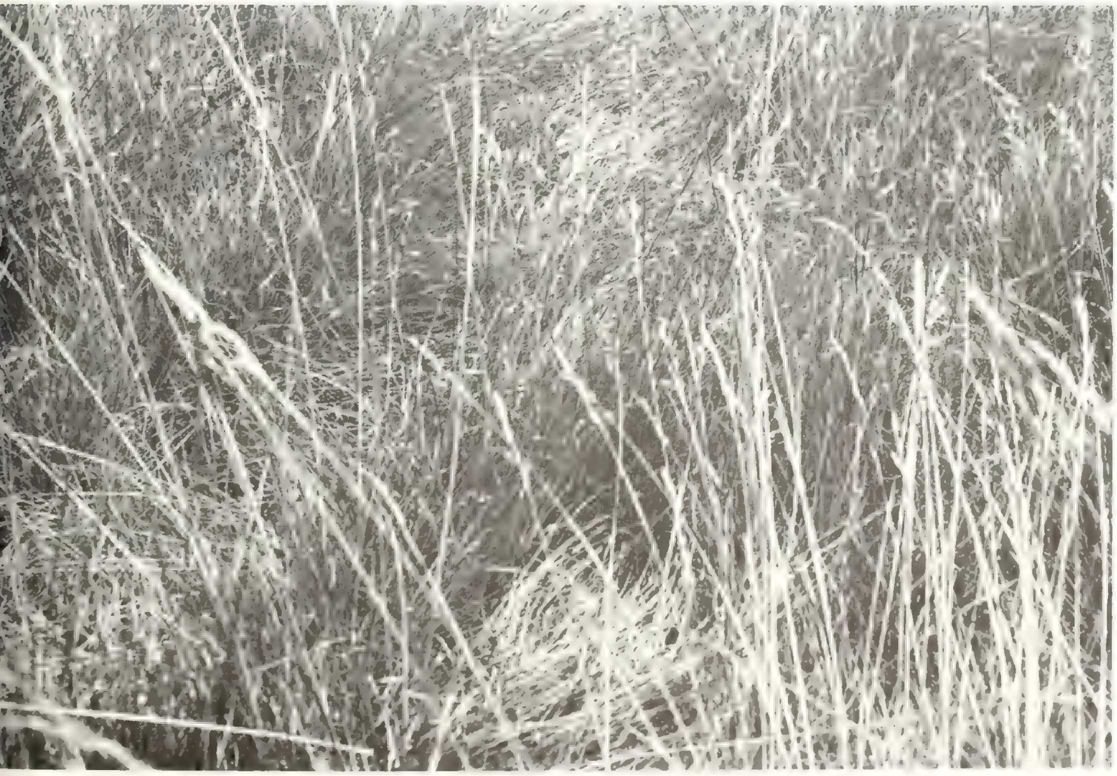
1978--green fescue, accounting for 80 percent of the cover composition, was the dominan plant within 40 years. Needlegrass and sedge (mainly ovalhead sedge) accounted for mos of the remaining cover. The area was well sodded. Soil, sloughing from the pedestals, had remained in the interspaces, resulting in a smoother surface.



1938



1956



1978

Figure 5

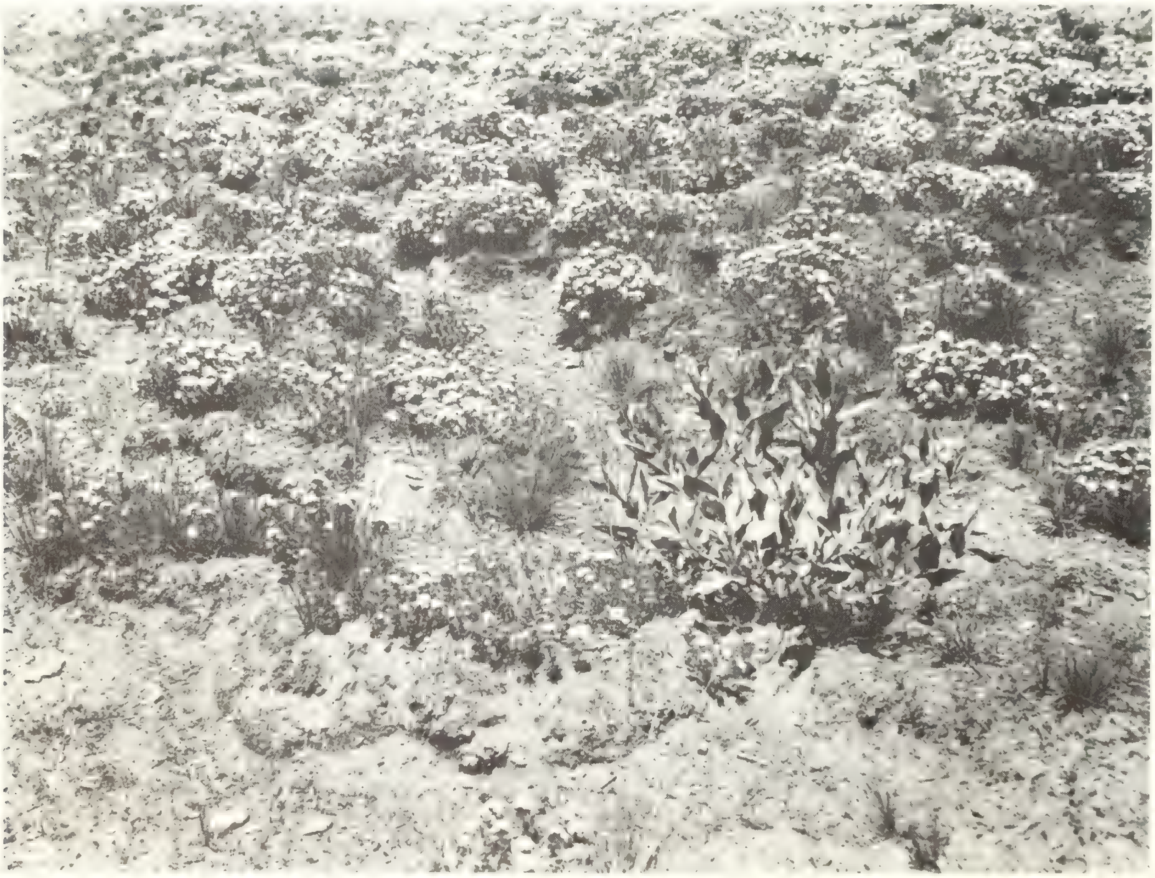
1938--a slope where grass sod was severely cut by sheep trailing; 90 percent of the green fescue root masses, contained within 7-inch topsoil pedestals, were dead, but the pedestals were becoming occupied by secondary species, primarily by Nuttall linanthastrum, sedges, and needlegrass. Groundsmoke (*Gayophytum* sp.) and fleeceflower were becoming established between the pedestals.

Figure 5

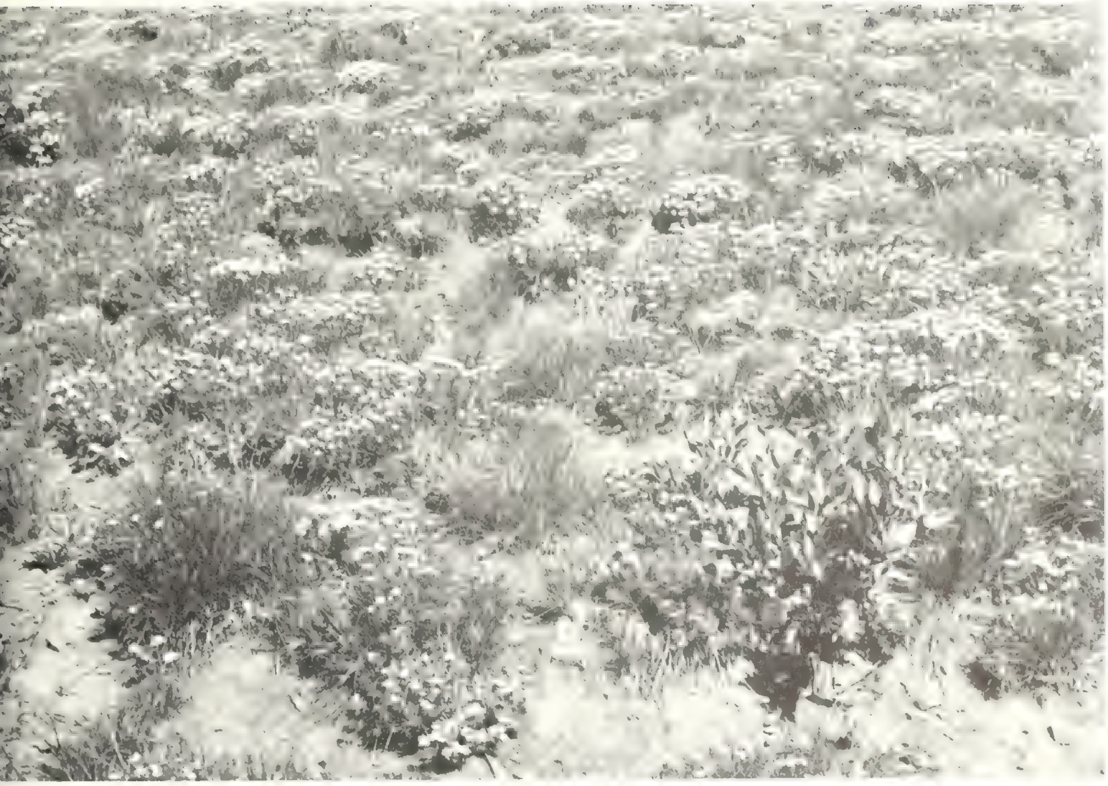
1956--green fescue cover had increased from 0.5 percent to 13 percent. Nuttall linanthastrum cover had almost doubled (7 to 12 percent), but that of needlegrass and sedge showed only a slight increase. The pedestaled root masses had become somewhat rounded, but the eroded surface configuration remained about the same.

Figure 5

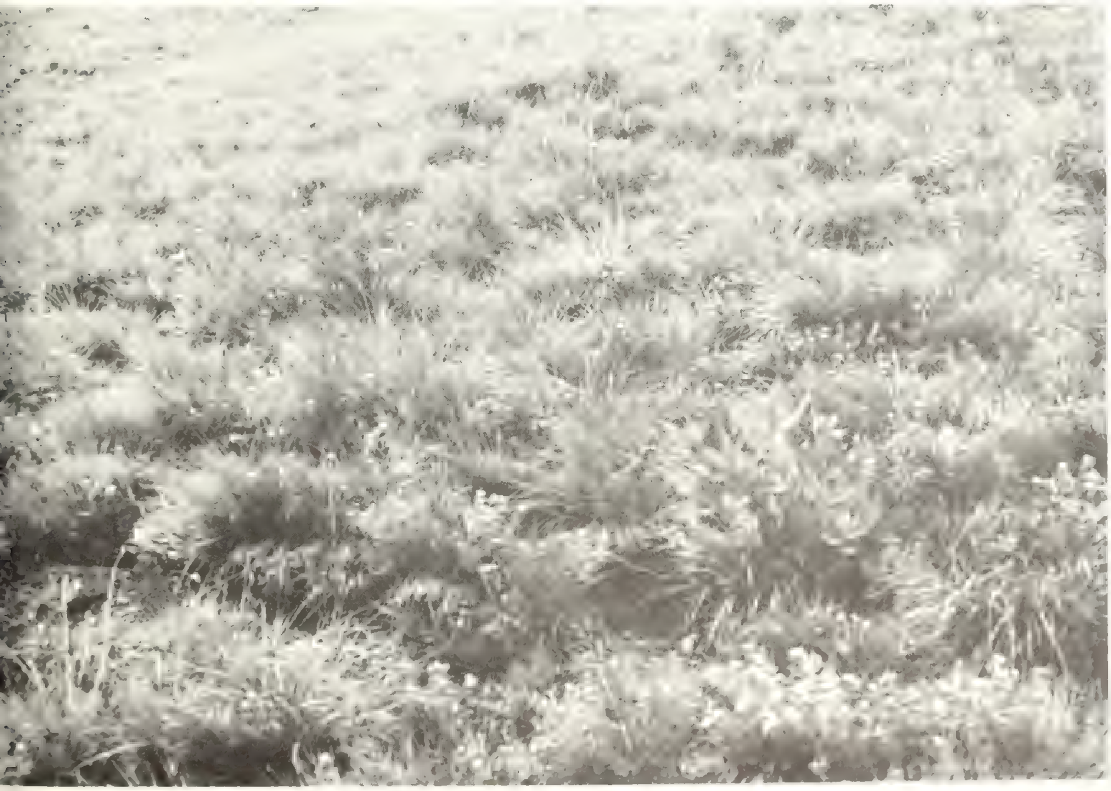
1978--density of green fescue had increased greatly and constituted half the vegetatio cover. Linanthastrum made up about 25 percent of the cover and Rydberg penstemon 10 percent. Western yarrow and eriogonum had also increased, but needlegrass and sedge had greatly decreased. Note that the fleeceflower plant in the 1938 photograph was still present 18 and 40 years later.



1938



1956



1978

Figure 6

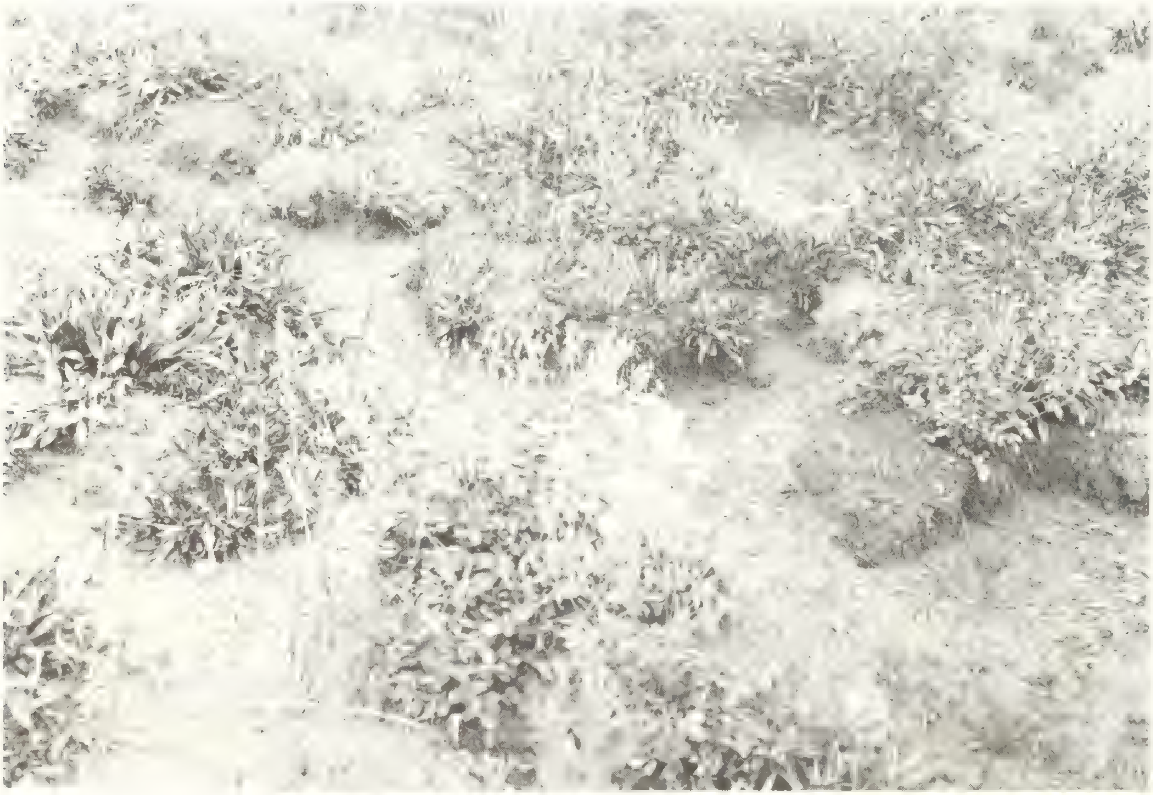
1938--a moist slope, with topsoil held in place by dead fescue root masses, was occupi by Rydberg penstemon, gland cinquefoil (Potentilla glandulosa Lindl.), Wyeth eriogonu and stickseed (Hackelia sp.). A few plants of needlegrass and fleeceflower were prese on the eroded soil between pedestals.

Figure 6

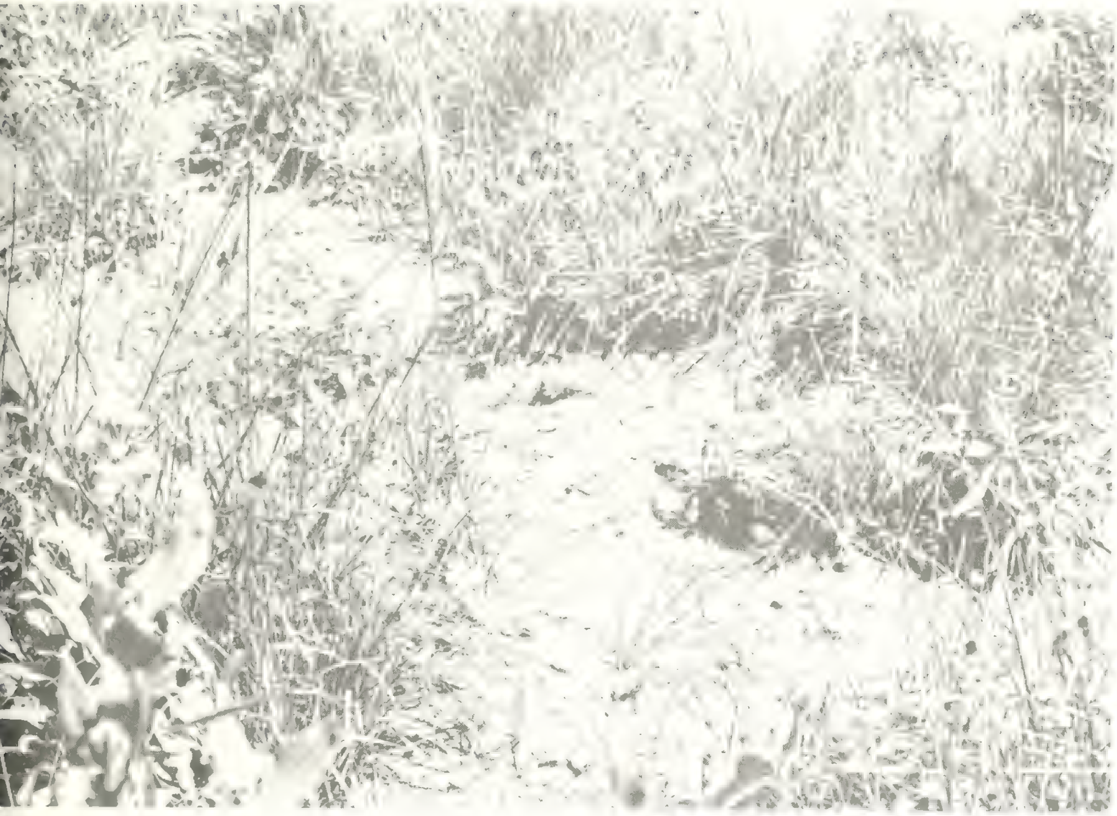
1956--the perennial forbs were still predominant, but green fescue and needlegrass had greatly increased and sedge was encroaching on the pedestals. Penstemon made up 33 pe cent of the cover, needlegrass 15 percent, and green fescue 38 percent. Barren soils between pedestals were still conspicuous.

Figure 6

1978--by 1968 (no photograph), grasses had increased and most perennial forbs had decreased, although many individual forb plants identified in 1938 were still present. Density of fleeceflower had greatly increased. In 1978 green fescue had largely replaced needlegrass as the dominant plant, fleeceflower had become the most abundant forb, gland cinquefoil was common, and the other forbs were still present. Pedestals, rounded off, could still be identified, and the plants growing on them had moved or were moving onto the spaces between pedestals.



1938



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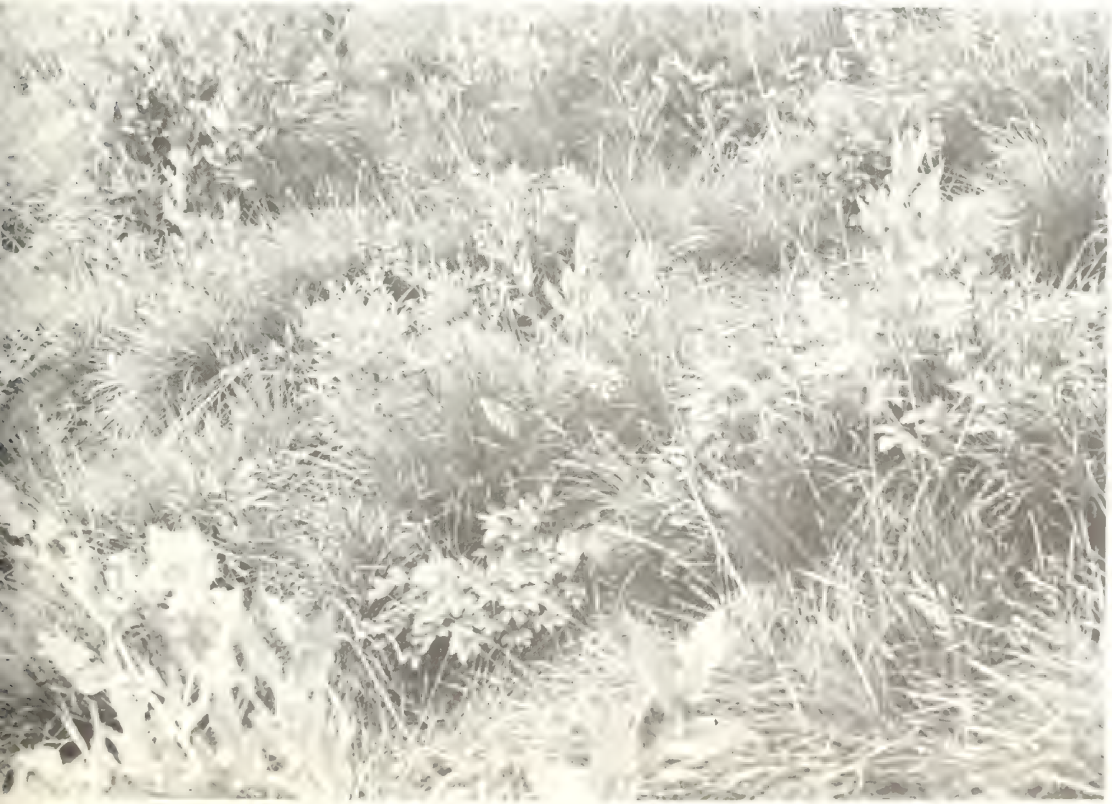


1978

Figure 7

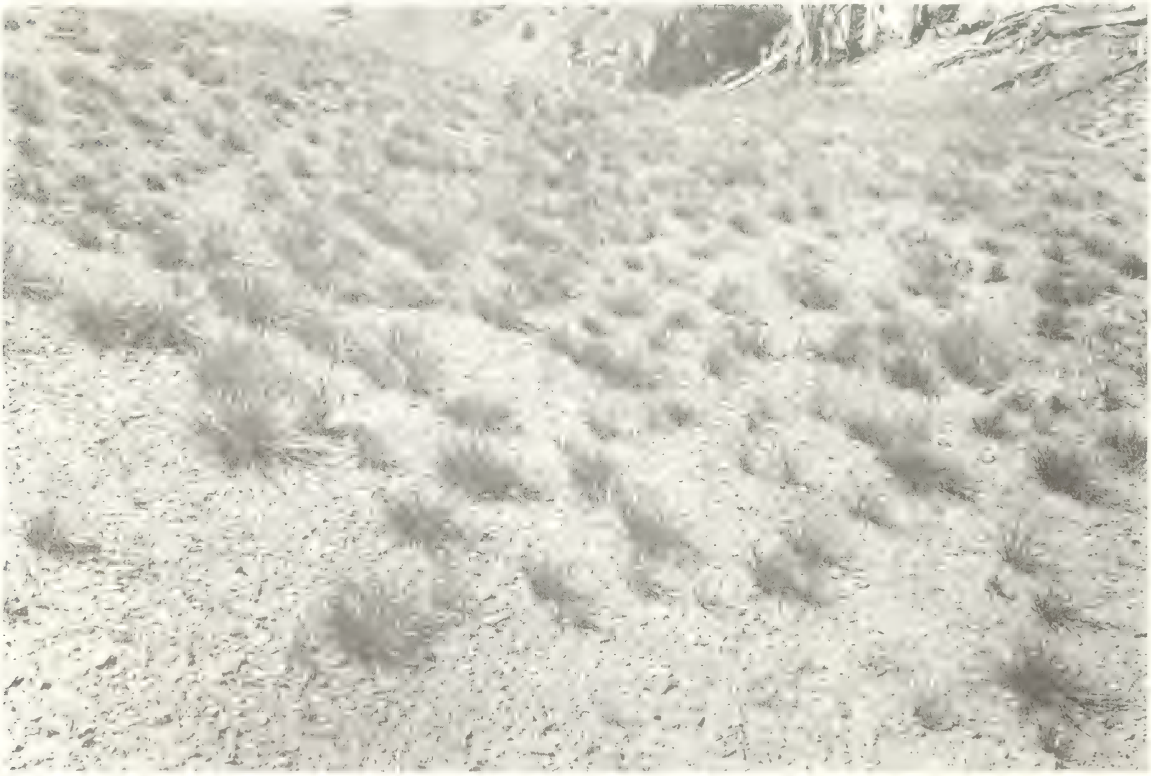
1938--years of trailing on this site had resulted in the loss of most topsoil by erosion and the elimination of green fescue. A few remnant soil pedestals (on the right and upper left) indicated the severity of the erosion. Needlegrass and a single plant of fleeceflower had become established on the pavement, and a few plants of Nuttall linanthastrum were established on pedestals.

Figure 7

1956--green fescue, spiked trisetum (Trisetum spicatum (L.) Richt.), sedge, and additional plants of fleeceflower had become established. Needlegrass was still the principal species.

Figure 7

1978--green fescue, sedge, needlegrass, and linanthastrum, in order of abundance, were the predominant species. Other perennial forbs that were becoming established in 1968 included western yarrow, pussytoes (Antennaria sp.), Rydberg penstemon, eriogonums, and fleabane. The fleeceflower, present in 1938, was still present, along with several new plants of the species. The remnant pedestals were still intact.



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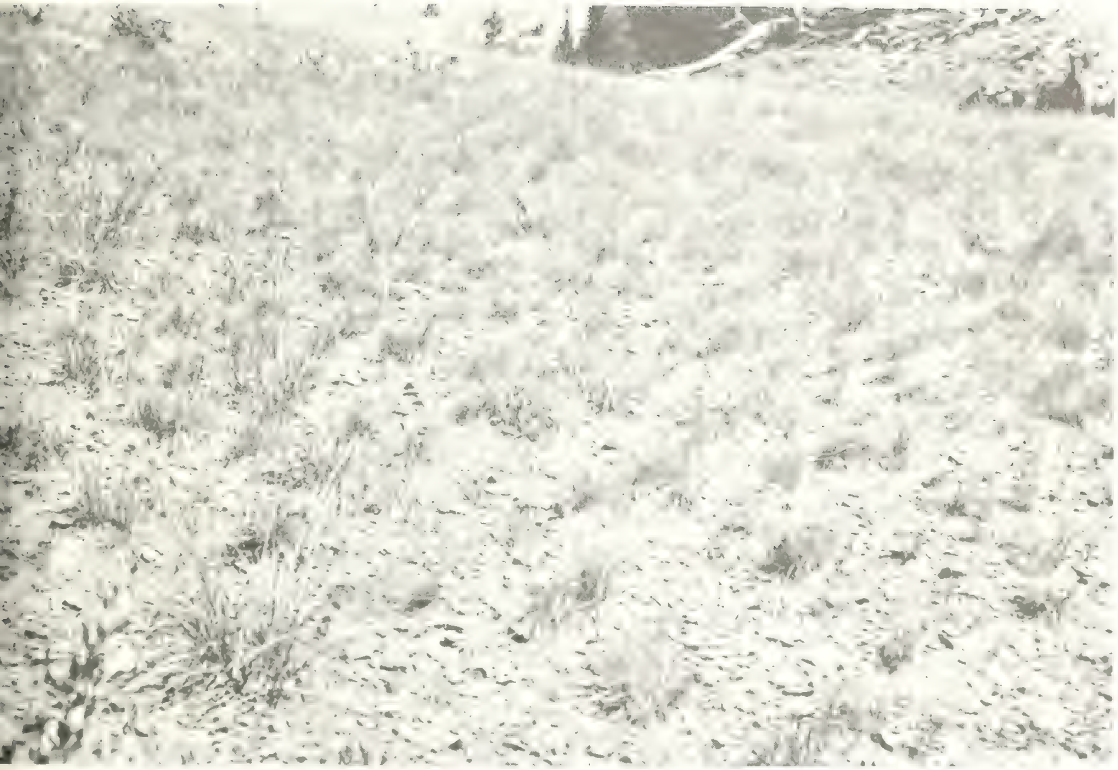

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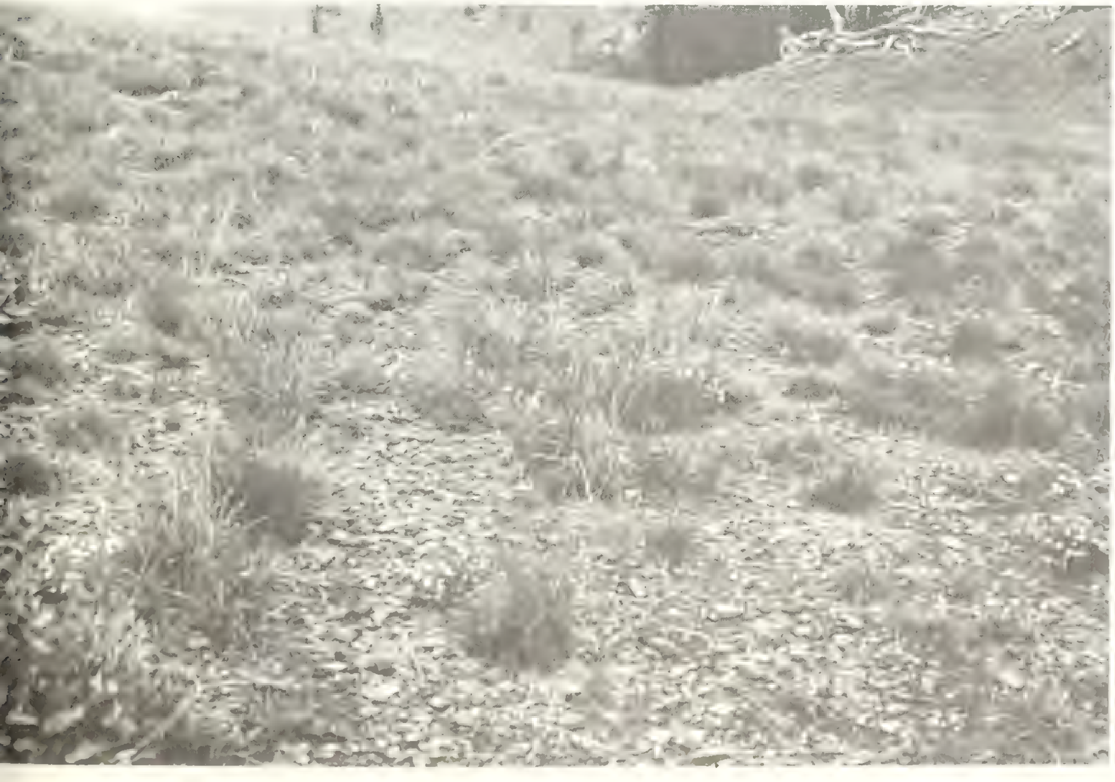

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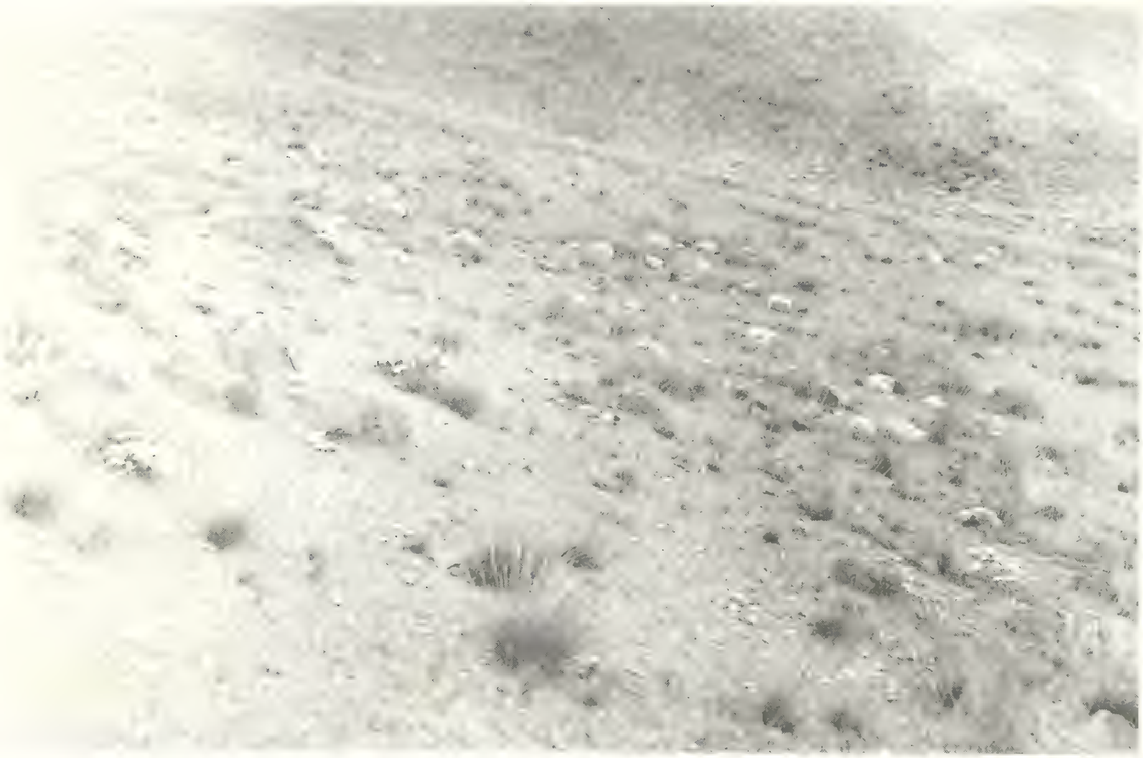

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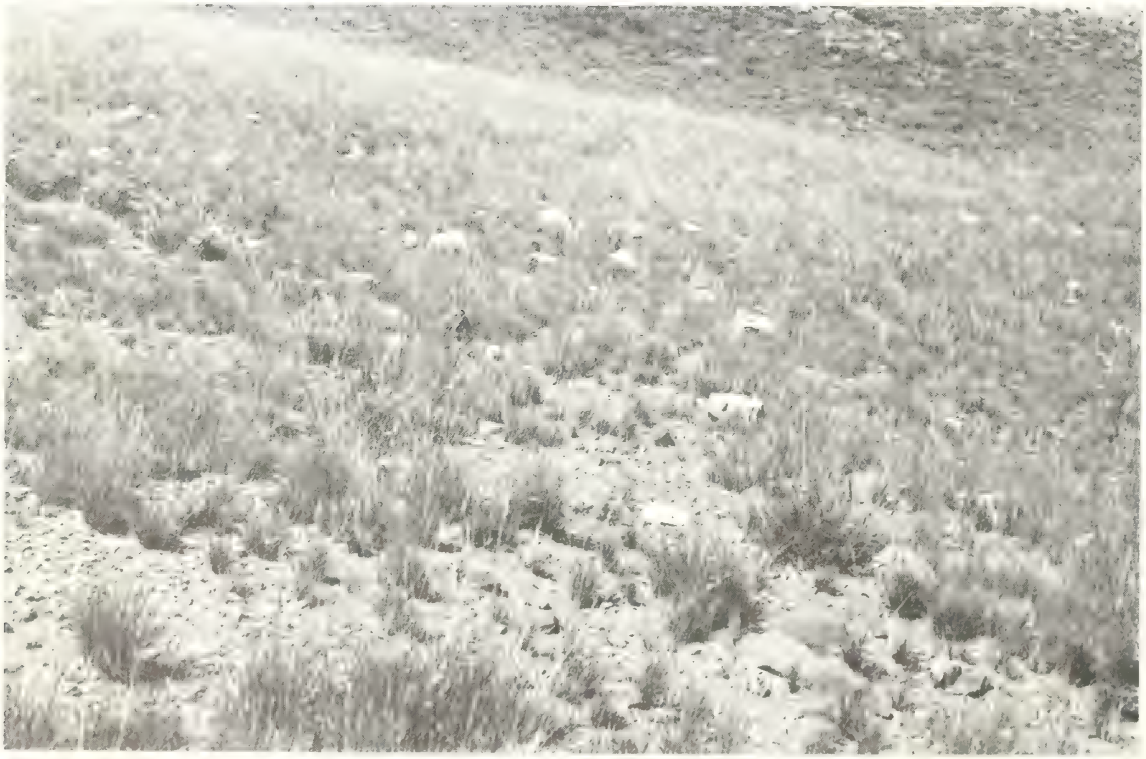


1960

igure 8

38--a site used as a bedground where most of the topsoil had been lost to erosion.
edlegrass and Nuttall linanthastrum were the only conspicuous species. The linan-
astrum was primarily restricted to growth on the remnant pedestals, whereas the
edlegrass plants were restricted mainly to growth on the extensive erosion pavement.

gure 8

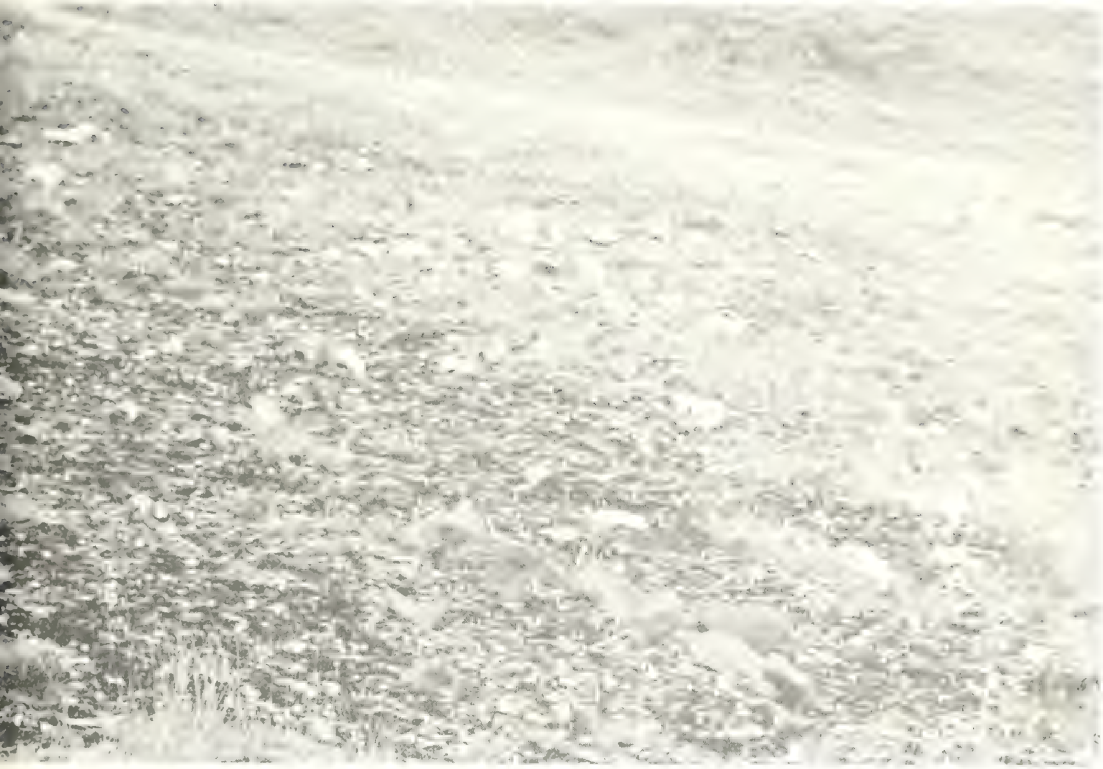
60--density of needlegrass had greatly increased on the erosion pavement. Green
scue, in good vigor, had established on the intact pedestals, although linan-
astrum, hidden by the grass herbage, was still present on the pedestals.

Figure 8 (continued)

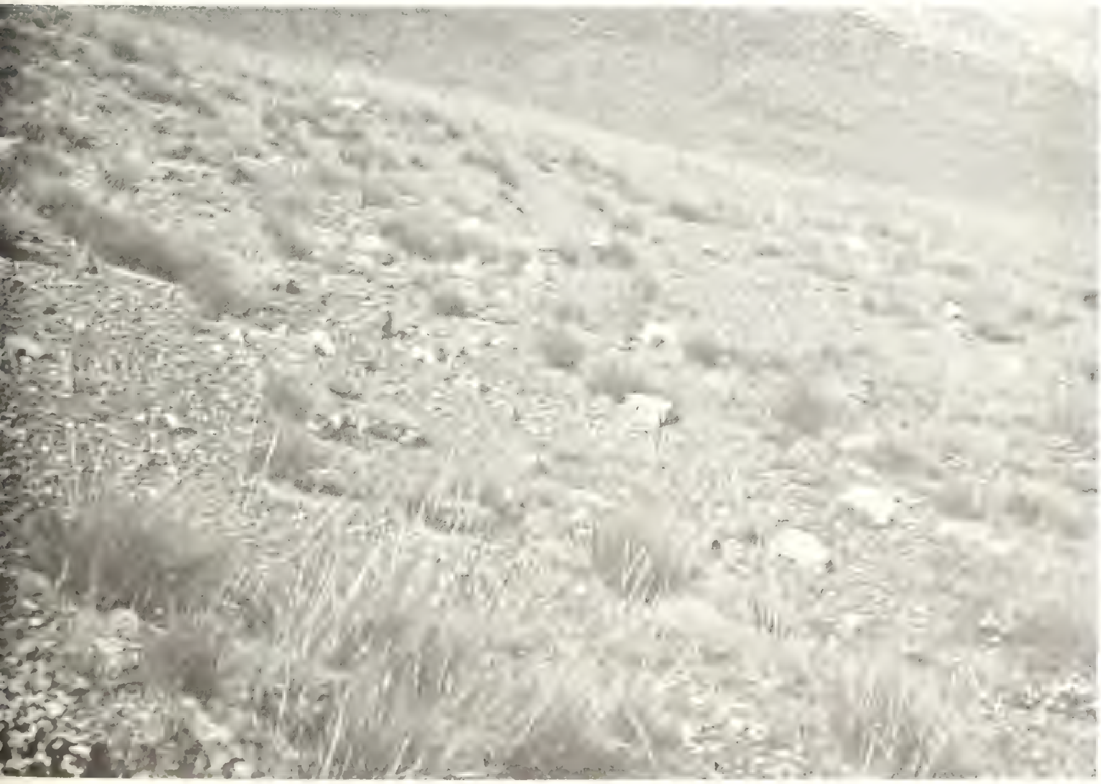
1968--the area had just been grazed by sheep, so herbage growth could not be compared with that in earlier photographs. Small plants of both needlegrass and green fescue were present in the area; most of the larger grazed plants were green fescue. There was an apparent loss, however, of the needlegrass plants that showed in the foreground of the 1960 photograph.

Figure 8

1978--the vegetation cover was similar to that in 1938, but green fescue had almost entirely replaced the needlegrass. Linanthastrum was still evident, and there were a fe plants of sedge, Wyeth eriogonum, and Rydberg penstemon. Erosion pavement was again a prominent feature of this site. Some pedestals present in 1938 were still intact.



1968



1978

Figure 9

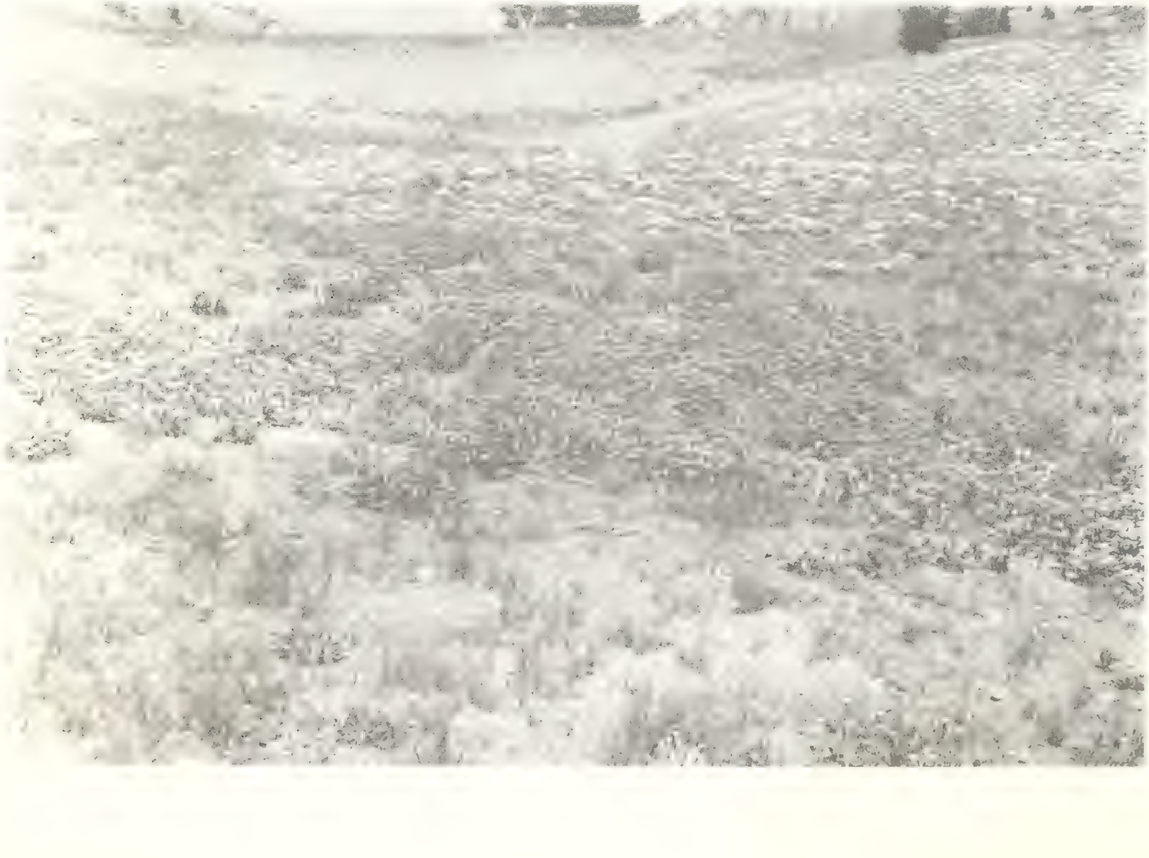
1938--a swale site where most of the topsoil had eroded away, but remaining soil depth and moisture were favorable for establishment of moderate to dense patches of Rydberg penstemon (center), Nuttall linanthastrum (upper center and right slope), and needlegrass. Sedges, eriogonums, and sandwort (Arenaria capillaris Foir.) were less prominent. Note the barren slope in the background.

Figure 9

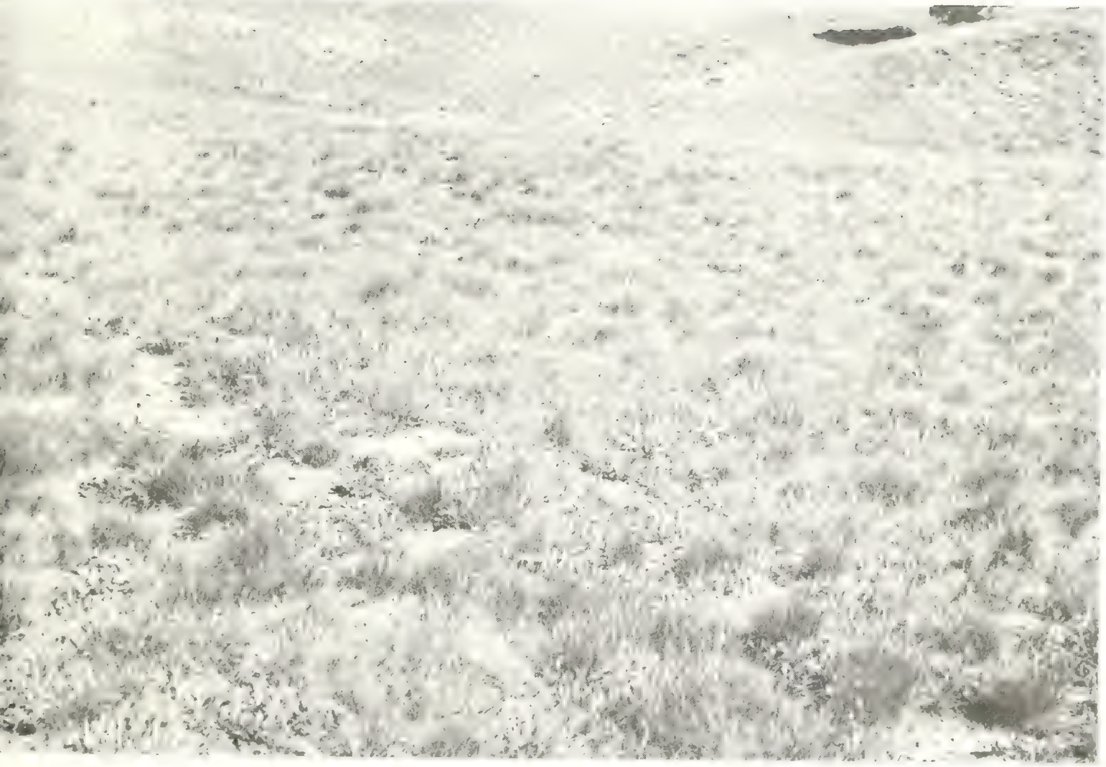
1956--after 18 years under reduced grazing, green fescue had reestablished on the site. Needlegrass, spiked trisetum, and sedge dominated the species composition. Penstemon, eriogonum, and linanthastrum had decreased, but total cover had increased. The barren slope in the background had greatly filled in with ovalhead sedge, needlegrass, spiked trisetum, and bottlebrush squirreltail.

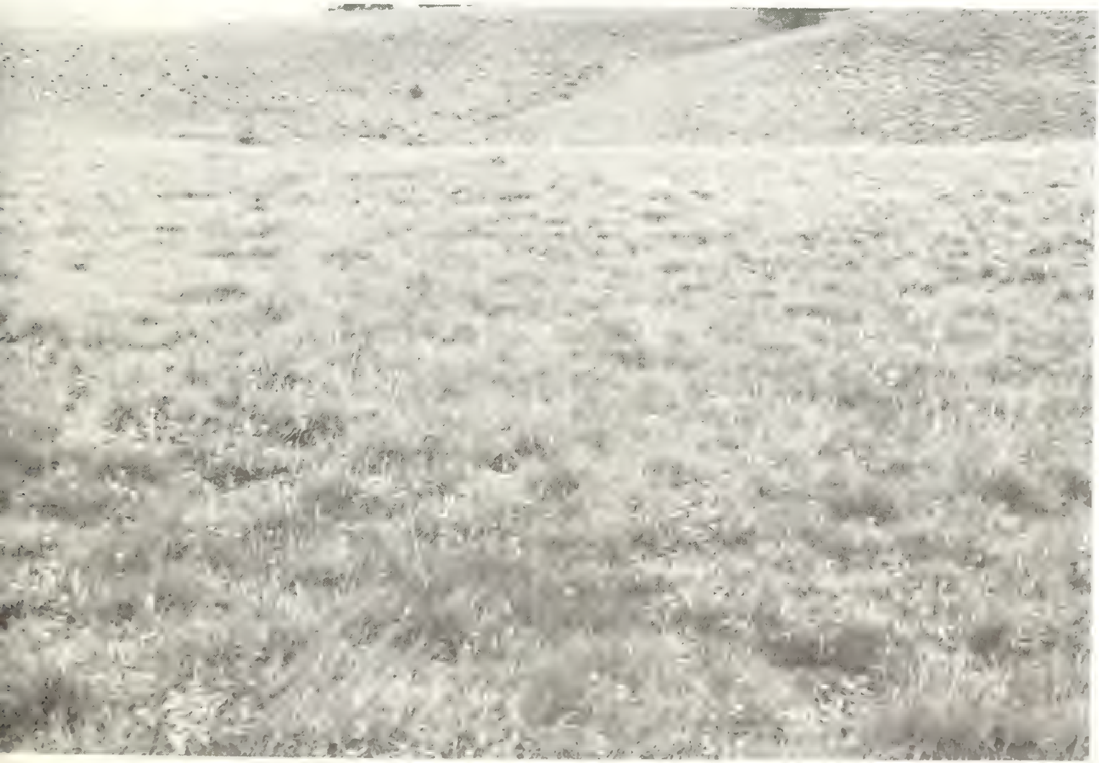
Figure 9

1978--after 40 years, green fescue dominated a dense stand of vegetation in the foreground and middle section. Penstemon and linanthastrum were still the main forbs, although they were not as abundant as in 1956 and 1968. Needlegrass and bottlebrush squirreltail were the main species on the slope in the background. In the foreground, about 30 percent of the area between plants was covered with litter. About 10 percent of the more eroded slope in the background was covered with litter.



1938


1956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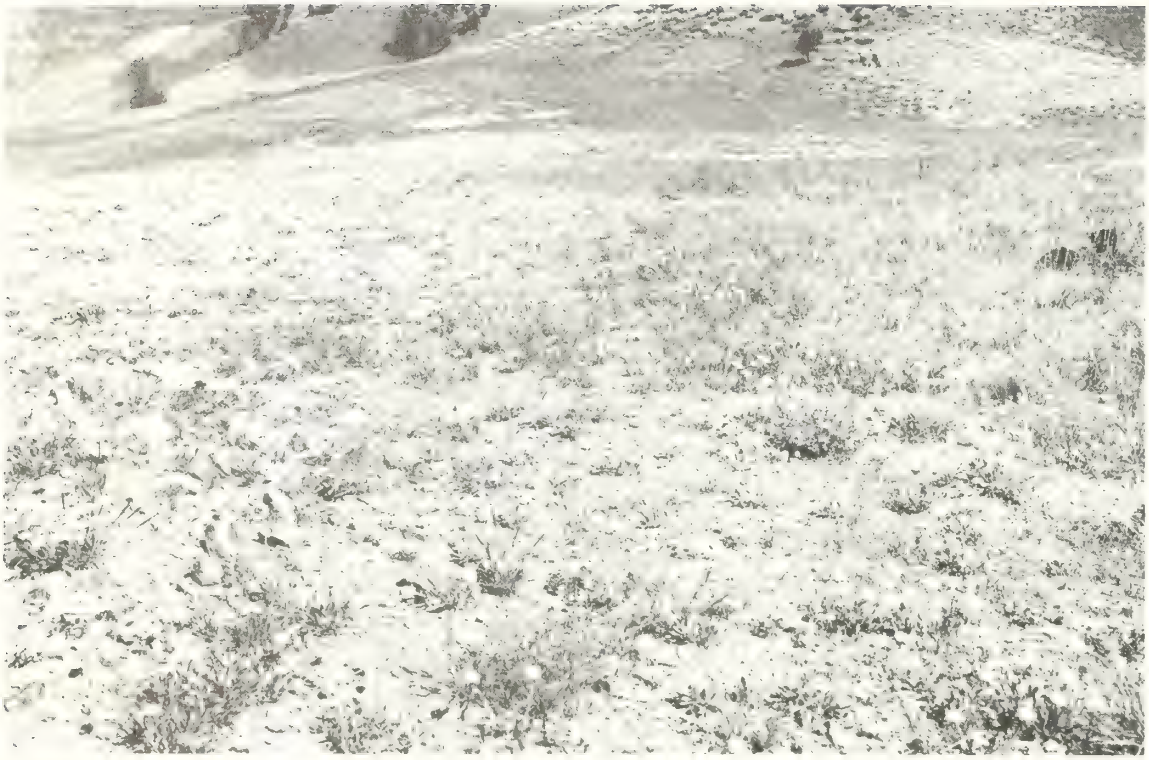

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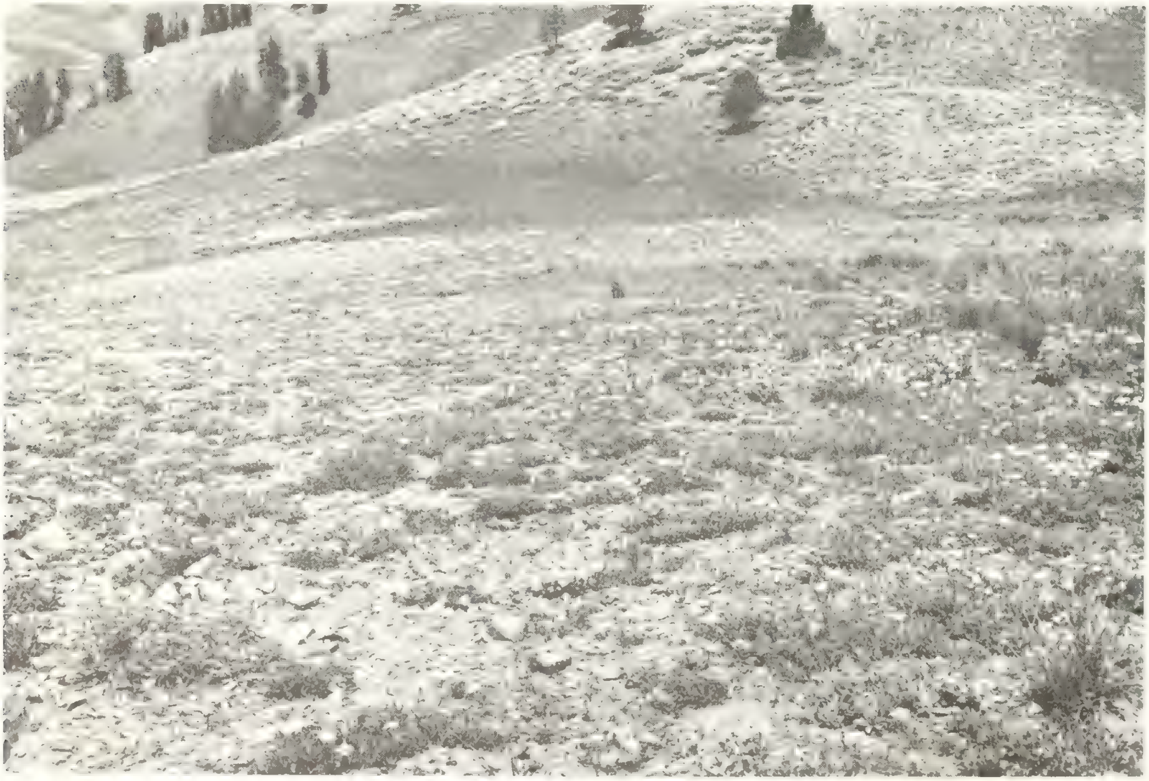


1956

re 10

--a bench site where a shallow topsoil was lost through erosion followed by light deposition (on the right). Piper eriogonum, alpine phacelia (*Phacelia alpina* .), ballhead gilia (*Gilia congesta* Hook.), and umbellate pussypaws (*Spraguea* *llata* Torr.) are prominent on the eroded site, and needlegrass, sedges, and flea-s on the deposited soil. The large grass plants in the foreground are bottle-h squirreltail.

re 10

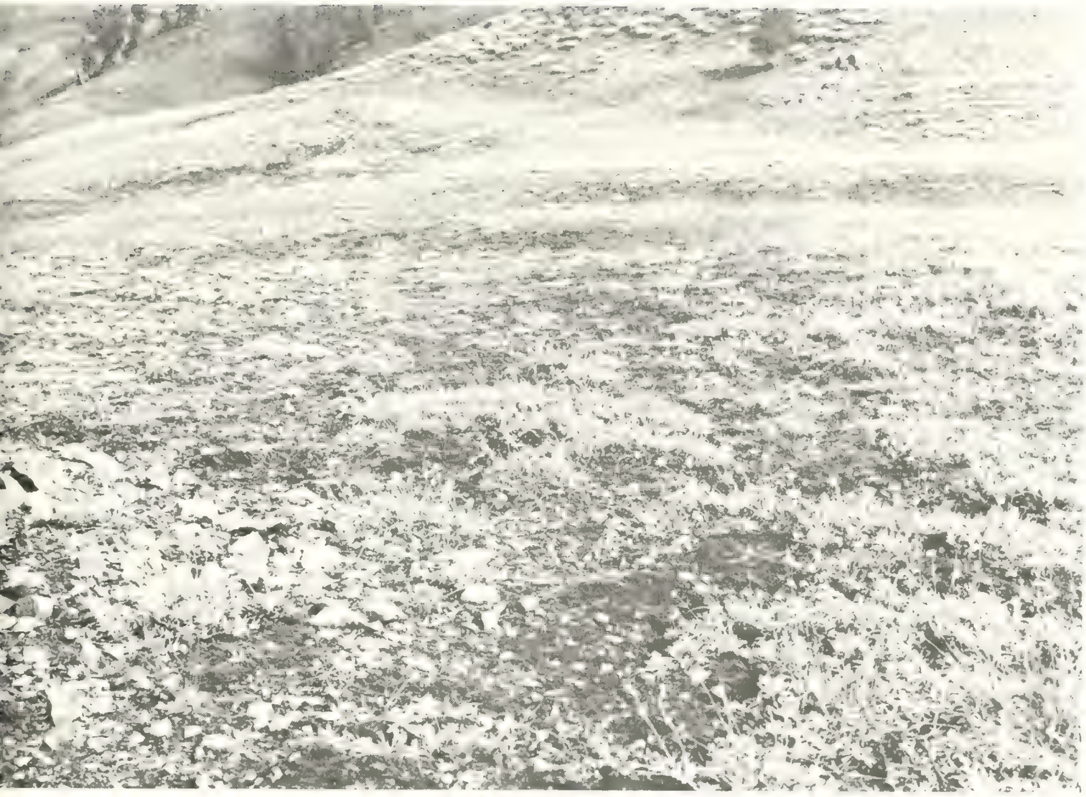
--there was little change in plant composition or cover. Piper and Wyeth eriogo-were the dominant species; ballhead gilia and umbellate pussypaws were still con-uous. Cover of sedges, fleabanes, and bottlebrush squirreltail had decreased. legrass seedlings and Rydberg penstemon were established on the eroded soil.

Figure 10 (continued)

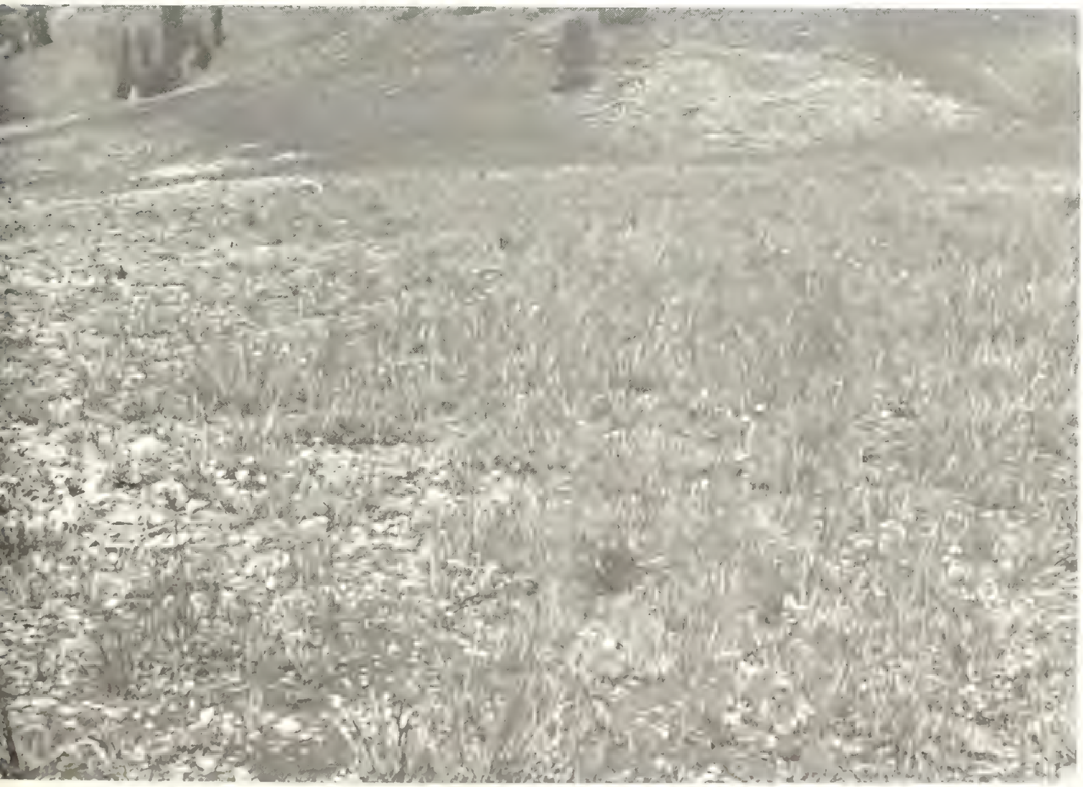
1968--the site, grazed 2 days before the photograph was taken, had changed little in cover since 1956; however, some shifts in composition had occurred. Eriogonums (mainly Wyeth eriogonum) were still dominant and needlegrass was the main grass species, but Rydberg penstemon and fleabanes were not observed and some plants of Nuttall linanthastrum, western yarrow, and sandwort, not recorded previously, were present.

Figure 10

1978--Wyeth eriogonum was the dominant species, accounting for 50 percent of the vegetation cover. Grasses had greatly increased and included California brome, oniongrass cutting wheatgrass, needlegrass, and green fescue, the latter accounting for 3 percent of the cover. The fescue was not recorded in earlier years.



1968



1978

Conclusions

The vegetation of Tenderfoot Basin has improved greatly since 1938. Obvious signs of improvement were the abundance of established fescue plants (and plants of other species palatable to sheep) on the better sites and the accumulation of litter. With good management practices, the Tenderfoot Basin range should continue to improve for several decades, particularly on less eroded sites that apparently are not yet supporting their green fescue potential. In the future, many sites may maintain only sparse stands of green fescue because of past soil erosion. Yet the density of secondary grasses and forbs appears to be sufficient to provide the cover necessary to prevent accelerated erosion.

Acknowledgments

We are grateful to Chris Maser (Bureau Land Management, Range and Wildlife Hab tat Laboratory, La Grande, Oregon) for the consultations, his critical review, and suggestions which greatly improved the manuscript.

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1980. Green fescue grassland: 40 years of secondary
succession. USDA For. Serv. Res. Pap. PNW-274, 39 p.,
illus. Pacific Northwest Forest and Range Experiment
Station, Portland, Oregon.

The 40-year succession of a depleted green fescue (*Festuca viridula*) subalpine grassland in the Wallowa Mountains, Oregon, was influenced by historic soil erosion. Range conditions of the grassland annually grazed by domestic sheep improved greatly between 1938 and 1978; most of the improvement occurred between the 30th and 40th years. Photographs illustrate the changes.

Keywords: Grassland management, succession, fescue, *Festuca*, grazing (range), subalpine grasslands.

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United States
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Forest and Range
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Research Paper
PNW-275

August 1980

Diameter and Height Growth of Suppressed Grand Fir Saplings After Overstory Removal

K.W. Seidel

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K. W. SEIDEL is a silviculturist at the Silviculture Laboratory, Pacific Northwe Forest and Range Experiment Station, Ben Oregon.

iameter and Height Growth f Suppressed Grand Fir Saplings fter Overstory Removal

eference Abstract

idel, K. W.
1980. Diameter and height growth of
suppressed grand fir saplings after
overstory removal. USDA For. Serv. Res.
Pap. PNW-275, 9 p., illus. Pacific
Northwest Forest and Range Experiment
Station, Portland, Oregon.

e 2- and 5-year diameter and height growth suppressed grand fir (Abies grandis ougl. ex D. Don) Lindl.) advance repro- ction was measured in central Oregon ter the overstory was removed. Multiple gression analyses were used to predict owth response as a function of individual ee variables. The resulting equations, though highly significant, explained only to 44 percent of the variation in growth. ve crown ratio gave the best single riable correlation for both diameter and ight growth. Height growth after release s similar to growth before release. Only gorous advance reproduction having live own ratios of 50 percent or more should considered as potential crop trees.

YWORDS: Increment (height), increment iameter), advance growth, release, grand r, *Abies grandis*.

Research Summary

Research Paper PNW-275
1980

In 1974, a study was begun to obtain information about the growth response of suppressed grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.) saplings after release by removal of the overstory. The purpose was to compare height growth before and after release, to compare diameter and height growth for several periods after release, and to develop an equation to predict diameter and height growth after release as a function of variables, such as live crown ratio, and initial height.

The study area is in an *Abies grandis*/*Linnaea borealis* plant community in the Ochoco National Forest, central Oregon. Before logging, there was a three-storied stand structure consisting of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), grand fir, western larch (*Larix occidentalis* Nutt.), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), and lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), averaging about 200 square feet of basal area per acre. After the overstory was removed, 115 grand fir saplings were selected for the study to include a wide range of vigor classes based on live crown.

Both diameter and height growth increas
significantly during the last 3-year pe
after release compared with the first 2
period. Height growth did not respond t
release compared with growth before rel
Live crown ratio gave the best single
variable correlation for both diameter
height growth; height growth before rel
also was a significant variable. The pr
diction equations accounted for only 17
44 percent of the variation in growth.

The best potential crop trees are vigor
advance reproduction having live crown
ratios greater than 50 percent and thos
with the greatest height growth before
release.

troduction

ny mixed conifer stands in the forests of
stern Oregon are two layered, consisting
a mature or overmature overstory and a
l1-stocked understory of true fir saplings
d poles. If sufficient trees of the
sired species remain after the overstory
removed and if they will respond to
lease, the use of advance reproduction
the new stand is better than relying on
uncertainties of obtaining new
generation.

ppressed advance reproduction of true
rs will respond to release by increased
ameter and height growth if the trees
ve relatively full crowns (Gordon 1973,
ssley 1976, Seidel 1977). In 1974, a
udy was begun to learn more about the
owth response that can be expected from
rious classes of suppressed fir saplings.
purpose of this study was to: (1)
mpare height growth before and after
lease, (2) compare rate of diameter and
ight growth for several periods after
lease, (3) screen specific variables for
tential inclusion in a model for pre-
cting diameter and height growth, and
estimate the coefficients for these
ediction equations and provide some index
their reliability.

Study Area

The study area is in the Big Summit District of the Ochoco National Forest about 40 miles[1] northeast of Prineville, Oregon, at an elevation of about 5,600 feet. The soil is a well-drained Regosol developed in dacite pumicite originating from the eruption of Mount Mazama (Crater Lake) 6,500 years ago. The ash layer has a fine sandy loam texture and is about 3 feet deep over the residual silty clay loam soil.

Before the overstory was logged, the timber stand consisted of a mixture of grand fir (Abies grandis (Dougl. ex D. Don) Lindl.), Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), western larch (Larix occidentalis Nutt.), and a few scattered ponderosa pine (Pinus ponderosa Dougl. ex Laws.) and lodgepole pine (Pinus contorta var. latifolia Engelm.). A three-storied stand structure existed before logging; it consisted of overmature old growth, smaller sawtimber, and advance reproduction averaging about 30,000 gross board feet (Scribner rule) per acre and 200 square feet of basal area per acre. After the overstory was removed only advance reproduction consisting of seedlings, saplings, and poles no larger than 6 inches in diameter at breast height (d.b.h.) remained.

The study area is located in an Abies grandis/Linnaea borealis plant community (Hall 1973). Ground vegetation is composed of genera, such as Bromus, Rosa, Arnica, Mitella, Anenome, and Ribes. Site index of grand fir in the area based on Schumacher's (1926) curves indicates a height of 50 feet at age 50, whereas Cochran's (1979) curves show 45 feet on a 50-year base.

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[1] Metric equivalents are given in the appendix.

Methods

The overstory was logged in 1974, and 115 grand fir saplings were selected in the 40-acre cutting unit. These study trees included a wide range of vigor classes from fully crowned trees to those with a relatively small crown; the trees were free from logging damage and infections of dwarf mistletoe. Trees were selected in an unordered sequence until specific crown classes were adequately sampled. Study trees were located on level ground and on slopes up to 33 percent. All aspects except south were sampled; only one tree was located on a southeast aspect, and three trees were on a slope facing southwest. Most sample trees were on the north, northwest, and west aspects. Height of the sample trees ranged from 2.9 to 12.2 feet (mean 6.8 feet), and diameter measured at 1 foot above the ground ranged from 0.55 inch to 2.9 inches (mean 1.4 inches). All trees within a 10-foot radius of each sample tree were cut to minimize the effect of competition from adjacent trees.

In the fall of 1974, 1976, and 1979 measurements taken on each sample tree were:

1. Stem diameter at ground level, 1 foot above the ground and one-half way up the bole to nearest 0.05 inch.
2. Double bark thickness at each diameter measurement point to nearest 0.05 inch.
3. Total height to nearest 0.1 foot.
4. Height growth during the past year, past 2 years, and past 5 years to nearest 0.1 foot.
5. Height to base of live crown to nearest 0.1 foot.
6. Average crown diameter at base of live crown to nearest 0.1 foot.

From these measurements, the variables--live crown ratio, crown volume, crown surface area, and bole area--of each tree were computed. In addition, several other ratios derived from the measured variable were calculated for use in the analyses.[2] Aspect and slope percentage were also measured for each tree.[3] Stepwise multiple regression procedures were then used to fi linear equations of the form $Y = b_0 + b_1 X_1 + b_2X_2 + \ldots b_nX_n$ to the data and to determine the equations of best fit. Four separate analyses were performed usin Y_1 = 2-year and 5-year diameter growth in inches and Y_2 = 2-year and 5-year height growth in feet. Values of Y_1 and Y_2 were subjected to a $\sqrt{Y + 1/2}$ transformatio to reduce the heterogeneity of variance. Paired t tests were used to test differenc between 2- and 5-year postrelease and prerelease growth rates and differences betwee annual growth rates for the first 2 years and final 3 years of the 5-year period aft release.

---

[2] See the appendix for independent variable and formulas used to calculate crown volum crown surface area, and bole area.

[3] Aspect was coded by the method proposed b Day and Monk (1974), in which the followin values were assigned to compass directions N, 14; NE, 15; E, 11; SE, 7; S, 3; SW, 2; W, 6; NW, 10.

esults

ameter Growth

ing the 5 years after the overstory was
oved, annual growth (1 foot above the
und) averaged 0.13 inch (table 1).
meter growth rate increased significantly
0.01)--more than threefold--from
5 inch per year the first 2 years of
period to 0.18 inch per year the last
ears. Growth of individual trees ranged
n 0 to 2.1 inches during the 5-year
iod.

iable equations for predicting diameter
wth could not be developed because of
small amount of variation accounted for
the independent variables (table 2),
nough all variables were significant
0.01). The best single variable equation
olved live crown ratio and explained
percent of the variation in diameter
wth during the first 2 years and
percent for the entire 5-year period.
addition of height growth for the 1st
2d years before logging raised the
lained variation to 44.1 percent (2-year
wth), but the addition of crown diameter
1-year height growth before release
y increased the explained variation to
percent (5-year growth).

Although none of the variables can be used to reliably predict diameter growth, vigorous trees (as indicated by live crown ratio) are more likely to grow faster than trees of poor vigor. For example, average annual diameter growth rate on trees with live crown ratios greater than 50 percent was about twice that of trees having live crown ratios less than 50 percent for both 2- and 5-year periods (table 1). These differences were significant ($P < 0.01$).

le 1--Periodic annual height growth before release and annual diameter and ght growth of suppressed grand fir saplings after release

ree vigor class	Number of trees	Before release		After release					
		1973-74	1970-74	1975-76		1977-79		1975-79	
		Height growth	Height growth	Diameter growth	Height growth	Diameter growth	Height growth	Diameter growth	Height growth
		Feet[2]	Feet[2]	Inches[2]	Feet[2]	Inches[2]	Feet[2]	Inches	Feet[2]
trees	107	0.14 ± 0.01	0.21 ± 0.01	0.05 ± 0.005	0.15 ± 0.01	0.18 ± 0.01	0.20 ± 0.02	0.13 ± 0.01	0.18 ± 0.01
ees with live crown ratio less than 50 percent	36	.09 ± .01	.12 ± .01	.03 ± .01	.09 ± .01	.12 ± .01	.17 ± .03	.08 ± .01	.14 ± .02
ees with live crown ratio more than 50 percent	71	.17 ± .01	.24 ± .02	.06 ± .01	.18 ± .01	.20 ± .01	.21 ± .02	.15 ± .01	.20 ± .02

leasured at 1 foot above the ground.

lean ± standard error.

Table 2--Relationship of independent variables to 2-year and 5-year diameter growth of suppressed grand fir saplings

Independent variables[1]	Equation	Percent of variation explained,[3] R^2	Standard error of estimate,[3] $S_{y \cdot x}$
			Feet
	2-YEAR DIAMETER GROWTH		
LCR	y[2] $= 0.6681 + 0.0019\,(\mathrm{LCR})$	30.0**	0.05
LCR, HG2	$y = 0.6775 + 0.0014\,(\mathrm{LCR}) + 0.0692\,(\mathrm{HG2})$	35.1**	.05
LCR, HG2, HG1	$y = 0.6759 + 0.0015\,(\mathrm{LCR}) + 0.1580\,(\mathrm{HG2}) - 0.3084\,(\mathrm{HG1})$	44.1**	.05
	5-YEAR DIAMETER GROWTH		
LCR	$y = 0.7851 + 0.0048\,(\mathrm{LCR})$	23.0**	.15
LCR, CD	$y = 0.6869 + 0.0044\,(\mathrm{LCR}) + 0.0300\,(\mathrm{CD})$	27.4**	.15
LCR, CD, HGI	$y = 0.6753 + 0.0052\,(\mathrm{LCR}) + 0.0300\,(\mathrm{CD}) - 0.3087\,(\mathrm{HG1})$	29.6**	.15

[1] LCR = live crown ratio (percent); HG2 = height growth 2 years before release (feet); HG1 = height growth 1 year before release (feet); CD = crown diameter (feet).

[2] $y = \sqrt{\text{Diameter growth in inches} + 0.5}$.

[3] Of transformed data.

**Significant at the 1-percent level.

Height Growth

The average annual height growth was 0.18 foot during the 5 years after release (table 1), and total growth of individual trees ranged from 0.2 foot to 3.9 feet. The rate of height growth increased significantly ($P < 0.01$) from 0.15 foot per year the first 2 years after release to 0.20 foot per year the last 3 years.

Height growth did not respond to release compared with equal periods before releas The average annual growth during the firs 2-year period before release increased by nonsignificant 7.1 percent after release- from 0.14 to 0.15 foot. For the entire 5 years after release, height growth decrea significantly ($P < 0.05$) by 14.3 percent (from 0.21 to 0.18 foot), compared with growth 5 years before logging (table 1).

amount of variation in height growth lained by the regression equations and independent variables involved are ilar to the diameter growth relations; variables were significant. Live crown io again was the best single variable ing the first 2-year period, explaining percent of the variation in height growth ble 3). Adding height growth for the 1st 2d years before release increased the to 44.2 percent. Only 23 percent of variation in 5-year height growth er release was explained by the three iables--height growth 5 years before ging, live crown ratio, and crown ume/diameter ratio.

The average height growth rate of more vigorous trees (live crown ratio greater than 50 percent) was twice that of trees with live crown ratios less than 50 percent in the first 2-year period and about 43 percent greater for the entire 5 years (table 1). These differences were significant ($P < 0.01$).

Damage and Mortality

Of the 115 study trees, 0.9 percent died the first 2 years after the overstory was removed, and 6 percent died in the following 3 years. Five trees had yellowish-brown, chlorotic-appearing needles on a portion of the crown, and the terminal bud of three trees had aborted. There was also evidence of damage to some trees from porcupines and pocket gophers.

le 3--Relationship of independent variables to 2-year and 5-year height growth of pressed grand fir saplings

ndependent variables[1]	Equation	Percent of variation explained,[3] R^2	Standard error of estimate,[3] $S_{y \cdot x}$
			Feet
	2-YEAR HEIGHT GROWTH		
R	y[2] $= 0.7089 + 0.0033$ (LCR)	30.0**	0.09
R, HG2	$y = 0.7332 + 0.0019$ (LCR) $+ 0.1793$ (HG2)	41.4**	.08
R, HG2, HG1	$y = 0.7317 + 0.0021$ (LCR) $+ 0.2652$ (HG2) $- 0.2983$ (HG1)	44.2**	.08
	5-YEAR HEIGHT GROWTH		
R	$y = 0.8103 + 0.0062$ (LCR)	17.5**	.23
R, HG5	$y = 0.8514 + 0.0037$ (LCR) $+ 0.0931$ (HG5)	20.8**	.23
R, HG5, CV/CD	$y = 0.8297 + 0.0049$ (LCR) $+ 0.1048$ (HG5) $- 0.0116$ (CV/CD)	22.7**	.22

CR = live crown ratio (percent); HG2 = height growth 2 years before release (feet); = height growth 1 year before release (feet); HG5 = height growth 5 years before ease (feet); CV/CD = crown volume (cubic feet)/crown diameter (feet).

$= \sqrt{\text{Height growth in feet} + 0.5}$.

f transformed data.

ignificant at the 1-percent level.

Discussion

Although a reliable growth prediction equation could not be developed from the data, it is obvious that vigorous advance reproduction with full crowns (fig. 1) have a better chance of responding rapidly after overstory removal than do trees with smaller crowns (fig. 2). For example, only 16 percent of trees in this study with live crown ratios of less than 50 percent grew 1.0 foot or more in height in the 5-year period, but 47 percent of trees with live crown ratios greater than 50 percent grew at this rate.

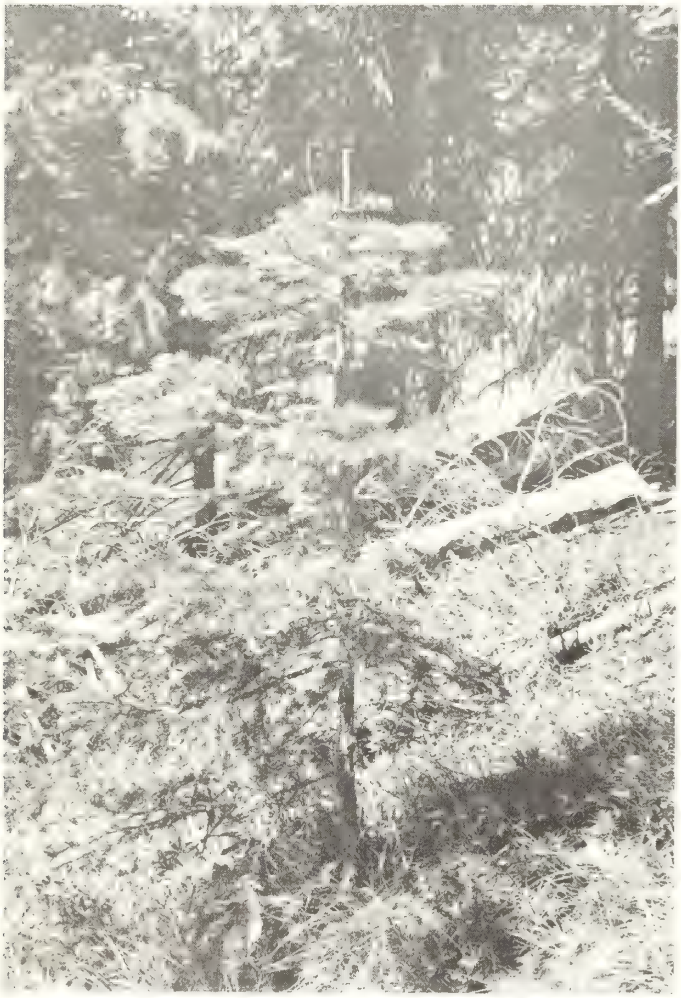

Figure 1.--A vigorous, full-crowned tree. In 1974, the live crown ratio was 78 percent. During the 5 years after release, the tree grew 2.3 feet in height and 1.35 inches in diameter (measured 1 foot above the ground).

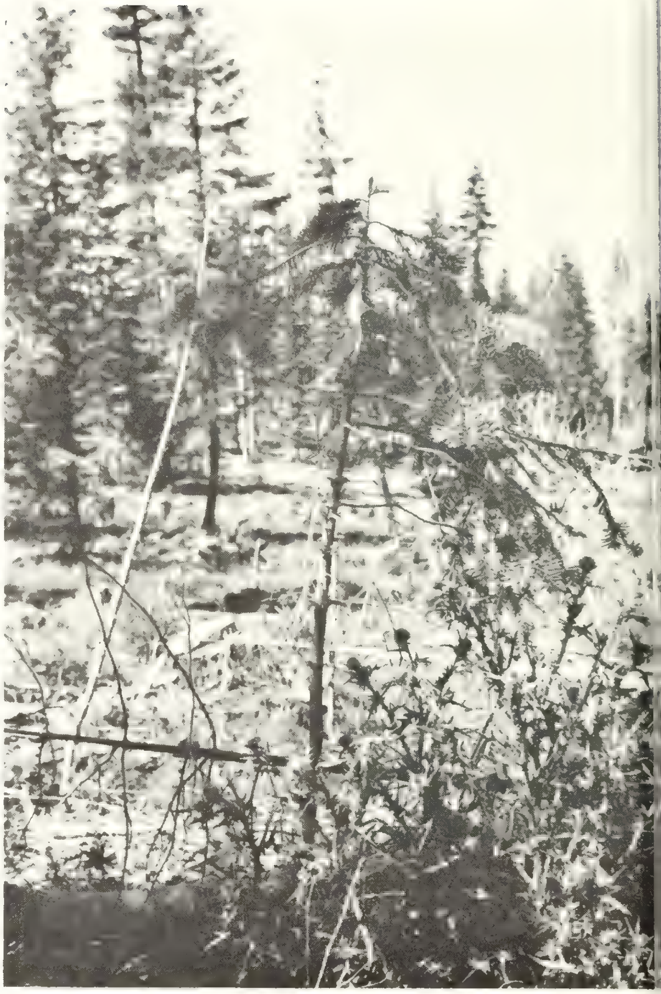

Figure 2.--A tree of low-vigor and small crown. In 1974, the live crown ratio was 34 percent. During the 5 years after release, the tree grew 0.3 foot in height and 0.15 inch in diameter (measured 1 foo above the ground).

nerally, the height growth of these trees s unchanged by release. Trees growing owly before release usually grew slowly ter release, whereas faster growing trees ntinued to grow at a faster rate similar the response of grand fir in northern aho (Ferguson and Adams 1979). The lack immediate response in height growth is milar to that for true firs in northern lifornia, where no height growth response curred until the 5th year after removal the overstory (Gordon 1973). On the other nd, Seidel (1977) found an immediate ight growth response of vigorous true fir central Oregon. Apparently, the growth sponse of suppressed true fir saplings ries from place to place. Differences in sponse after release may be related to e degree of suppression provided by the erstory. A more rapid response might be pected of less severely suppressed true r advance reproduction growing under a cal western larch or lodgepole pine erstory than of regeneration growing der a dense overstory of grand fir or uglas-fir.

had thought the variables crown volume d surface area and various ratios using ese variables would explain a consider- le amount of the variation in growth. is was not the case, however. It may be at the equations used to calculate these own parameters are too crude to accurately scribe the photosynthetic area of the ee.

Although height growth increased somewhat during the last 3 years compared with the first 2 years after release, the average growth rate was slow (about 0.2 foot per year). One factor in decisions concerning use of advance reproduction or planted stock is their potential rate of height growth. Slow growth of the advance true fir reproduction would favor planting of fast growing species, such as Douglas-fir or western larch. In areas where problems with pocket gophers or porcupines make establishment of seedlings difficult, however, retaining vigorous advance reproduction may be desirable even if a height growth comparison favors planted seedlings. It appears that only saplings having a live crown ratio of at least 50 percent should be considered as potential crop trees. Desirable crop trees are those with relatively full crowns and the greatest height growth before release.

Even after careful overstory removal and slash disposal, advance reproduction may be clumpy, requiring planting between clumps, along skid trails, and in landings.

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ppendix

Metric equivalents.

1 mile = 1.61 kilometers
1 foot = 0.3048 meter
1 inch = 2.54 centimeters
1 square foot per acre = 0.2296 square meter per hectare

Crown volume, crown surface area, and e area equations.

Crown volume.

Crown volume was calculated as the volume of a cone for trees with a maximum crown diameter at the base of the crown.

$$\text{rown volume} = \frac{\pi r^2 h}{3} = 1.0472\ r^2 h;$$

where r = crown radius at base, and h = crown length. For trees where the maximum crown diameter did not occur at the base of the crown, the volume of a cone frustum was added to the cone volume.

$$\text{rustum volume} = \frac{\pi h_1}{3}\ (r_1^2 + r_1 r_2 + r_2^2);$$

where r_1 = radius at base of crown, r_2 = radius at maximum crown width, and h_1 = length from base of crown to point of maximum crown width.

Crown surface area.

Crown surface area was calculated as the surface area of a cone for trees with the maximum crown diameter at the base of the crown.

$$\text{own surface area} = \pi r \sqrt{r^2 + h^2}\ ;$$

where r = crown radius at base, and h = crown length.

For trees where the maximum crown diameter did not occur at the base of the crown, the surface area of a cone frustum was added to the cone surface area.

$$\text{Frustum surface area} = \pi (r_1 + r_2) \sqrt{h_1^2 + (r_1 - r_2)^2}\ ;$$

where r_1 = radius at base of crown, r_2 = radius at maximum crown width, and h_1 = length from base of crown to point of maximum crown width.

3. Bole area.

Bole area of each segment of the stem was calculated as:

$$\text{Bole area} = \frac{\pi h(d_1 + d_2)}{24.0}\ ;$$

where d_1 = diameter of large end of segment, d_2 = diameter of small end of segment, and h = length of segment.

C. Independent variables used in regression analyses.

X_1	Stem diameter 1 foot above the ground
X_2	Total height
X_3	Height growth in the past year (before release)
X_4	Height growth in the past 2 years (before release)
X_5	Height growth in the past 5 years (before release)
X_6	Live crown ratio (crown length/total height)
X_7	Crown volume
X_8	Crown surface area
X_9	Bole area
X_{10}	Crown volume/bole area
X_{11}	Crown surface area/bole area
X_{12}	Aspect
X_{13}	Slope
X_{14}	Crown diameter
X_{15}	Crown length
X_{16}	Height to live crown
X_{17}	Crown volume/height to live crown
X_{18}	Crown surface area/height to live crown
X_{19}	Crown volume/crown diameter
X_{20}	Crown surface area/crown diameter
X_{21}	Crown volume/crown length
X_{22}	Crown surface area/crown length

GPO 991-294

Seidel, K. W.
1980. Diameter and height growth of suppressed grand fir saplings after overstory removal. USDA For. Serv. Res. Pap. PNW-275, 9 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

The 2- and 5-year diameter and height growth of suppressed grand fir (Abies grandis (Dougl. ex D. Don) Lindl.) advance reproduction was measured in central Oregon after the overstory was removed. Multiple regression analyses were used to predict growth response as a function of individual tree variables. The resulting equations, although highly significant, explained only 17 to 44 percent of the variation in growth. Live crown ratio gave the best single variable correlation for both diameter and height growth. Height growth after release was similar to growth before release. Only vigorous advance reproduction having live crown ratios of 50 percent or more should be considered as potential crop trees.

KEYWORDS: Increment (height), increment (diameter), advance growth, release, grand fir, Abies grandis.

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Pacific Northwest
Forest and Range
Experiment Station

Research Paper
PNW-276
August 1980

The Outlook for Housing in Japan to the Year 2000

Michihiko Ueda and David R. Darr

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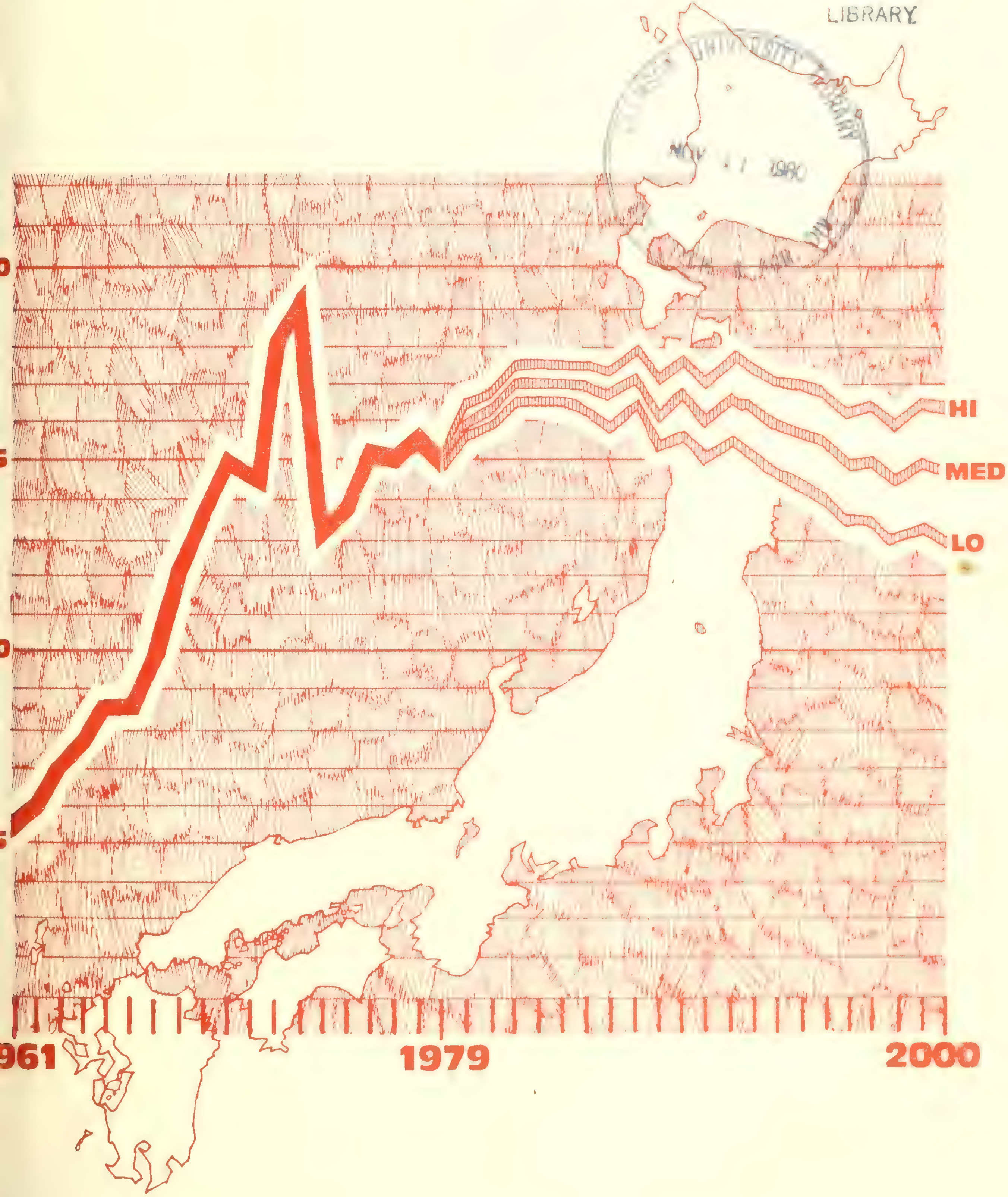

Authors

At the time this study was done, MICHIHIKO UEDA was a private consultant. DAVID R. DARR is principal economist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

In part, this report is based on a study by Michihiko Ueda in cooperation with the State of Washington Department of Natural Resources and USDA Forest Service, Pacific Northwest Forest and Range Experiment Station.

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e Outlook for Housing in pan to the Year 2000

ference Abstract

a, Michihiko, and David R. Darr.
980. The outlook for housing in Japan to the year 2000. USDA For. Serv. Res. Pap. PNW-276, 25 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

sing demand in Japan is analyzed in ns of new household formations, ancies, and replacements of housing ck. Total number of starts is projected stay near current levels or decline, ending on assumptions about replacement ands. This contrasts with rapid growth number of starts during the 1960's and ly 1970's.

words: Housing starts, trading policy ternational), import/export (forest ducts), Japan.

esearch Summary

search Paper PNW-276

80

ormation on the likely course of the ber of housing starts in Japan in the ure provides a useful, albeit only tial, data base for judging future ands by Japan for imported construction erials. In this report, the demand for housing is assumed to be generated from ee sources: formation of new households, ancies, and replacements.

mation of new households will decline in future, reflecting the age distribution the Japanese. The population has signif- ntly more people aged 20 to 40. As s group ages, current levels for the ber of new households cannot be ntained.

Vacancies, including second homes, will probably become more important in the future as a proportion of the total number of housing units. This assumption is based in part on an apparent upward trend in ownership of second homes, both as vacation villas and as condominiums for occasional use in congested metropolitan areas.

Demand for replacement housing in the future is especially difficult to project because historical data reflect replacement of substandard housing constructed in the decade after World War II. Historical data suggest that replacement demand is positively related to rates of economic growth. In recognition of this relationship and of uncertainties about the future, we projected three series of replacement demands, corresponding with low, medium, and high rates of economic growth. Under the high assumption, annual removals would rise throughout the projection period, reaching 1,035,000 units in 2000. Under the medium assumption, annual removals would generally vary between 800,000 and 900,000 units, and for the low assumption, between 700,000 and 800,000 units. The historic high was 856,000 units in 1972. These relatively high numbers of removals occur despite an assumed decline in the ratio of removals to total number of housing units. The ratio is expected to decline because of a gradual increase in the quality of housing. The number of housing units, however, is assumed to increase over time to satisfy replacement demand.

Our projections of the total number of housing starts generated by all three sources of demand depend on the rate of economic growth assumed. Under conditions of high economic growth, the total number of housing starts increases to 1.795 million units in 1987 and then declines to 1.636 million in 2000. The assumption of medium rates of economic growth results in some increase in the number of starts to 1.708 million in 1987 and then a decline to 1.465 million in 2000. Under the low assumption, the number of starts stays near current levels until 1987 and then declines to 1.289 million in 2000.

The possibility of relatively stable or declining numbers of housing starts in Japan over the next two decades contrasts sharply with the experience of the past two decades when the number of starts doubled between 1961 and 1973. The type of housing constructed in the future, the average floorspace per unit, and the volume of lumber used per unit of floorspace will influence consumption of lumber in the future and thus demand for imports. We could find little basis for doubting that historical trends in these factors will continue. Housing constructed mostly of wood will continue to decline as a proportion of housing starts, the average floorspace per housing unit will continue to increase, and the average volume of lumber consumed per unit of floorspace will probably continue to decrease. A relatively stable to declining pattern for the number of housing starts in Japan, however, would be a significant shift from the historical pattern. This possibility should be considered in judging future market prospects in Japan.

A relatively stable to declining patter for Japanese housing starts in the futu has implications for future research to judge the impact of demands by Japan on U.S. timber supply-demand situation. Future research should concentrate more analysis of the interactions of the Uni States and other sources of supply. Ev with a relatively stable demand situati in Japan, there would be potential for increases or decreases in U.S. exports, depending on the situations in competin supply areas. U.S. producers intereste the Japanese market should consider the resource situations in competing supply areas when they formulate long-term marketing strategies.

ontext for the Study

ormation on long-term prospects for U.S.
de in timber products is essential for
ging the long-term U.S. domestic timber
ply-demand situation. For example, the
est and Rangeland Renewable Resources
nning Act of 1974 (U.S. Laws, Statutes,
. Public Law 93-378) mandates "an
lysis of present and anticipated uses,
and for, and supply of the renewable
ources, with consideration of the inter-
ional resource situation, and an emphasis
pertinent supply and demand and price
ationship trends." Economic intelligence
long-term trade prospects is also neces-
y for U.S. firms to formulate marketing
ategies; development of export markets
be a long, expensive undertaking and
ds to be guided by analysis of long-term
spects.

purpose of this report is to present
ormation on prospects for Japan's
sing industry to the year 2000--the
ber and type of housing starts and
rage floorspace. Admittedly, infor-
ion on Japan's housing industry provides
y part of the information necessary to
ge what the Japanese market might be for
. producers over the next two decades.
ormation is also needed on prospects for
plies to the Japanese market from
peting supply areas. In 1978, 37
cent of Japan's consumption of saw logs
supplied by Japanese producers,
percent by the United States, 15 percent
the Soviet Union, 2 percent by New
land, and 17 percent by all other
rces, primarily countries in Southeast
a (Forestry Agency of Japan 1979).
rease or decrease in supplies from any
peting source could affect prospects for
. exports.

In addition, the home construction industry accounts for only about three-fourths of the lumber used in Japan. Growth or decline in the remaining end-use industries could affect prospects for U.S. exports.

There is little doubt about the significance of housing starts in judging the prospects for U.S. markets, even though they are only a partial measure of long-term demand by Japan for U.S. timber products. The rapid rise in U.S. export of softwood logs to Japan in the 1960's and early 1970's parallels the rise in housing starts in Japan (fig. 1). Export of softwood lumber from the United States to Japan, primarily from Alaska, also increased at the time housing starts increased in Japan.

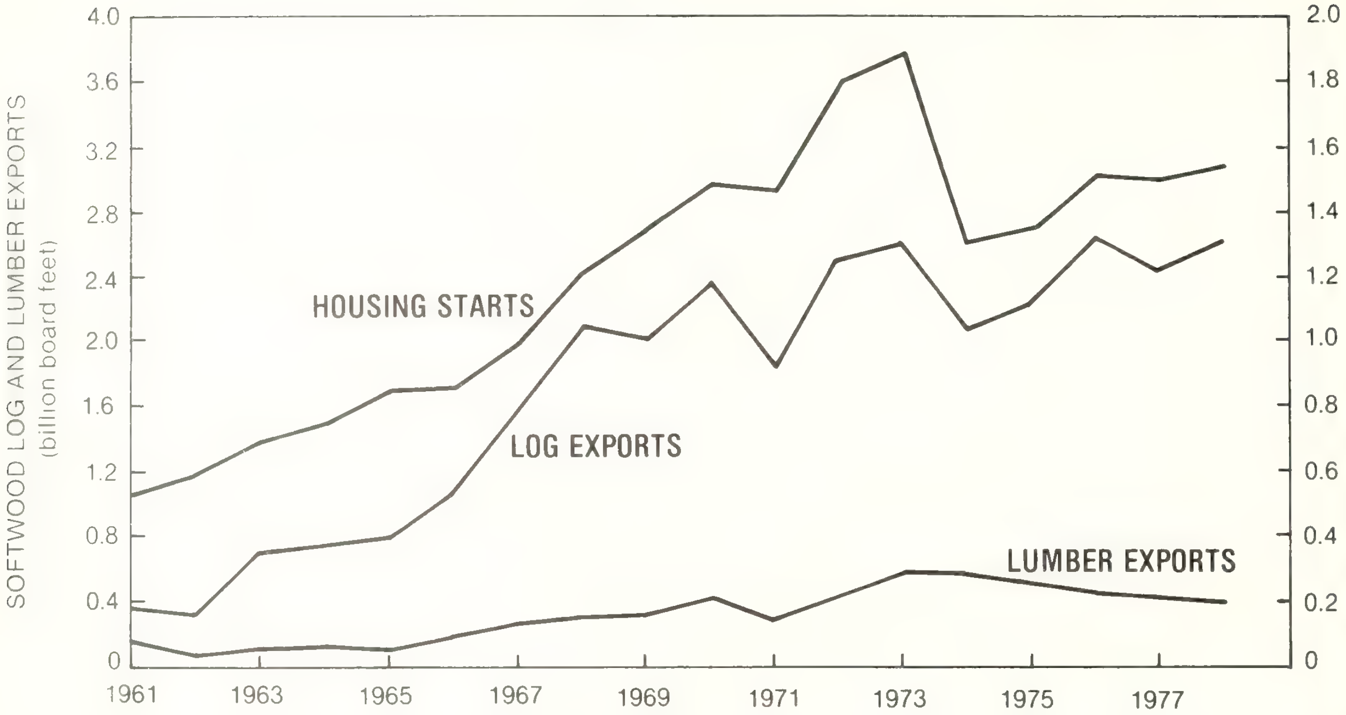

Figure 1.--Housing starts in Japan and U.S. softwood log and lumber exports to Japan, 1961-78. (Sources: U.S. Department of Commerce (monthly) and Office of Prime Ministe (monthly).)

The export of logs versus lumber to Japan is another uncertainty in judging market prospects from a U.S. perspective. Rationales can be developed for an expansion of softwood lumber exports at the expense of softwood log exports; labor costs are rising more rapidly in Japan than in the United States, and this would lead to increased export of lumber. Lumber producers in the Pacific Northwest are becoming less competitive in midwestern and eastern markets of the United States. This will increase the incentive for timber processors in the Pacific Northwest to develop offshore markets, such as Japan.

Rationales can also be developed for continued export of logs. Thousands of jobs are involved in processing imported logs in Japan. Government policies in Japan are generally sensitive to issues related to employment and thus favor con- tinued importation of logs. Sizes, grad and standards for lumber consumed in Jap differ from those of the United States. The proximity of processors and consumer in Japan under current trade patterns facilitates marketing of lumber in Japan and is an argument for continued export logs.

Information in this report should be interpreted as a general indicator of future demand by Japan for construction materials, regardless of the source. In interpreting this information the reader should keep in mind the additional types information needed to judge market prospects.

neral Approach to
ojection of Housing
arts

demand for new housing can be separated
three categories: formation of
tional households; an inventory of
nt units for sale or rent, or held for
r purposes, such as second homes; and
acement of housing units destroyed or
rwise removed from the inventory. This
of viewing the demand for new housing
developed by Marcin (1977) for use in
ecting U.S. housing starts and is the
roach used in this study to project
ing starts in Japan.

projections are not based on a tradi-
al economic framework for relating
ly and demand functions for housing.
ain (1979) proposed such a framework
analysis of the longrun supply of new
ing construction in the United States.
intent of our report is to point out
direction that housing starts in Japan
t take in the future.

Formation of New Households

Headship Rates

In the projection of household formations, headship rates (the ratio of number of households to the number of people in the selected component of the population) are related to various components of the population, and both headship rates and population are projected to the year 2000; for example, in table 1, 39.7 percent of males aged 20-29 were heads of household in 1975.

In general, the headship rate in Japan has increased over time. This reflects in part rising standards of living which have enabled two or more families sharing a housing unit to move into separate quarters. In addition, the headship rates in tables 1 and 2 probably reflect a change in lifestyles in Japan. More younger (age 20-39) and older (age 60+) people are moving into separate living quarters. This contrasts with traditional family patterns of two or more generations sharing the same housing unit.

The headship rates shown in tables 1 and 2 are for all types of households, including two or more families sharing the housing unit. The total number of households is synonymous with the term "ordinary households."

The headship rates for ordinary households were projected to 2000 by sex and age group (tables 1 and 2). In the projections, special consideration was given to the historical trend in headship rates for each group. In addition, growth in headship rates is expected to decline because of a slowdown in economic growth over the next two decades compared with the past two decades. A slowdown in economic growth would slow the tendency of families sharing a housing unit to move into separate living quarters.

Table 1--Proportion of males in Japan considered heads of households, by age group and type of household, for selected years, 1960-20

Year	Household				Household				Household			
	All	Nuclear[1]	1 Person	Other[2]	All	Nuclear[1]	1 Person	Other[2]	All	Nuclear[1]	1 Person	Oth
	Age group 20-29				Age group 30-39				Age group 40-49			
1960	0.234	0.161	0.018	0.055	0.710	0.480	0.008	0.222	0.889	0.603	0.007	0.
1965	.297	.202	.053	.042	.742	.547	.013	.182	.884	.608	.010	.
1970	.334	.214	.085	.035	.773	.604	.021	.148	.883	.618	.014	.
1975	.397	.248	.120	.029	.803	.636	.036	.131	.900	.647	.020	.
1979	.445	.266	.153	.026	.818	.655	.045	.118	.895	.652	.024	.
1980	.455	.270	.160	.025	.822	.660	.048	.114	.895	.655	.025	.
1981	.465	.274	.167	.024	.826	.665	.051	.110	.896	.658	.026	.
1982	.476	.278	.174	.024	.831	.670	.054	.107	.896	.660	.027	.
1983	.484	.281	.180	.023	.835	.674	.057	.104	.897	.663	.028	.
1984	.493	.284	.186	.023	.839	.678	.060	.101	.897	.665	.029	.
1985	.501	.287	.192	.022	.844	.682	.063	.099	.898	.668	.030	.
1986	.509	.290	.199	.022	.849	.686	.066	.097	.898	.670	.031	.
1987	.522	.293	.202	.027	.854	.690	.069	.095	.899	.673	.032	.1
1988	.523	.295	.207	.021	.858	.693	.072	.093	.900	.675	.033	.1
1989	.528	.297	.211	.020	.864	.698	.075	.091	.902	.678	.034	.1
1990	.534	.299	.215	.020	.867	.699	.078	.090	.903	.680	.035	.1
1991	.540	.301	.219	.020	.872	.702	.081	.089	.905	.683	.036	.1
1992	.545	.303	.223	.019	.877	.705	.084	.088	.906	.685	.037	.1
1993	.550	.305	.226	.019	.882	.708	.087	.087	.908	.688	.038	.1
1994	.554	.306	.229	.019	.886	.710	.090	.086	.909	.690	.039	.1
1995	.557	.307	.232	.018	.889	.712	.092	.085	.911	.693	.040	.1
1996	.561	.308	.235	.018	.892	.714	.094	.084	.912	.695	.041	.1
1997	.563	.309	.236	.018	.895	.716	096	.083	.915	.698	.042	.1
1998	.563	.309	.237	.017	.898	.718	0.098	.082	.916	.700	.043	.1
1999	.565	.310	.238	.017	.901	.720	0.100	.081	.918	.702	.044	.1
2000	.566	.310	.239	.017	.904	.722	0.102	.080	.902	.704	.045	.1

Year	All	Nuclear[1]	1 Person	Other[2]	All	Nuclear[1]	1 Person	Other[2]
	Age group 50-59				Age group 60+			
1960	0.936	0.573	0.012	0.351	0.728	0.285	0.023	0.420
1965	.939	.623	.014	.302	.753	.337	.028	.391
1970	.940	.644	.018	.278	.768	.388	.028	.352
1975	.941	.638	.024	.279	.758	.430	.033	.295
1979	.941	.640	.030	.270	.762	.470	.037	.255
1980	.941	.641	.031	.168	.763	.480	.038	.245
1981	.941	.642	.032	.266	.764	.488	.039	.237
1982	.941	.643	.033	.264	.765	.496	.040	.229
1983	.941	.644	.035	.262	.766	.504	.041	.221
1984	.941	.645	.036	.260	.767	.512	.042	.213
1985	.941	.646	.037	.258	.768	.520	.043	.205
1986	.941	.647	.038	.256	.769	.526	.044	.199
1987	.942	.648	.040	.254	.770	.532	.045	.193
1988	.942	.649	.041	.252	.771	.538	.046	.187
1989	.942	.650	.042	.250	.772	.544	.047	.181
1990	.942	.651	.043	.248	.773	.550	.048	.175
1991	.943	.652	.045	.246	.774	.554	.049	.171
1992	.943	.653	.046	.244	.775	.558	.050	.167
1993	.943	.654	.047	.242	.776	.562	.051	.163
1994	.943	.655	.048	.240	.777	.566	.052	.159
1995	.944	.656	.050	.238	.778	.570	.053	.155
1996	.944	.657	.051	.236	.780	.573	.054	.153
1997	.944	.658	.052	.234	.782	.576	.055	.151
1998	.944	.659	.053	.232	.784	.579	.056	.149
1999	.945	.660	.055	.230	.786	.582	.057	.147
2000	.945	.661	.056	.228	.788	.585	.058	.145

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[1] Household consists of a married couple only, married couple and children, father and children, or mother and children.

[2] Head of household lives with people other than spouse or children.

Source: Office of Prime Minister (1961, 1966, 1971, 1976).

Household				Household				Household			
All	Nuclear1/	1 Person	Other2/	All	Nuclear1/	1 Person	Other2/	All	Nuclear1/	1 Person	Other2/
- - - - -Age group 20-29- - - - -				- - - - -Age group 30-39- - - - -				- - - - -Age group 40-49- - - - -			
0.021	0.006	0.008	0.007	0.058	0.034	0.009	0.015	0.157	0.103	0.017	0.037
.039	.007	.024	.008	.057	.029	.018	.010	.134	.083	.025	.026
.051	.006	.036	.009	.054	.026	.021	.007	.118	.067	.030	.021
.068	.006	.053	.009	.056	.027	.023	.006	.107	.058	.033	.016
.077	.006	.062	.009	.057	.027	.025	.005	.104	.055	.036	.013
.079	.006	.064	.009	.058	.028	.025	.005	.103	.054	.036	.013
.081	.006	.066	.009	.059	.028	.026	.005	.103	.054	.037	.012
.083	.006	.068	.009	.059	.028	.026	.005	.103	.054	.037	.012
.085	.006	.070	.009	.060	.029	.026	.005	.103	.054	.037	.012
.087	.006	.072	.009	.061	.029	.027	.005	.103	.054	.038	.011
.089	.006	.074	.009	.061	.029	.027	.005	.102	.053	.038	.011
.091	.006	.076	.009	.062	.030	.027	.005	.102	.053	.038	.011
.092	.006	.077	.009	.063	.030	.028	.005	.103	.053	.039	.011
.093	.006	.078	.009	.063	.030	.028	.005	.103	.053	.039	.011
.095	.006	.080	.009	.064	.031	.028	.005	.103	.053	.039	.011
.096	.006	.081	.009	.065	.031	.029	.005	.103	.053	.040	.010
.098	.006	.083	.009	.065	.031	.029	.005	.102	.052	.040	.010
.099	.006	.084	.009	.066	.032	.029	.005	.102	.052	.040	.010
.100	.006	.085	.009	.067	.032	.030	.005	.102	.052	.040	.010
.101	.006	.086	.009	.067	.032	.030	.005	.102	.052	.040	.010
.102	.006	.087	.009	.069	.033	.031	.005	.103	.052	.041	.010
.103	.006	.088	.009	.069	.033	.031	.005	.103	.052	.041	.010
.103	.006	.088	.009	.070	.033	.032	.005	.103	.052	.041	.010
.104	.006	.089	.009	.071	.034	.032	.005	.103	.052	.041	.010
.104	.006	.089	.009	.072	.034	.033	.005	.103	.052	.041	.010
.105	.006	.090	.009	.072	.034	.033	.005	.103	.052	.041	.010
- - - - -Age group 50-59- - - - -				- - - - - Age group 60+ - - - - -							
0.161	0.086	0.027	0.048	0.115	0.029	0.043	0.043				
.184	.091	.039	.054	.128	.032	.055	.041				
.190	.086	.054	.050	.148	.036	.070	.042				
.173	.071	.066	.036	.163	.036	.090	.037				
.182	.076	.076	.030	.171	.036	.102	.033				
.184	.075	.079	.030	.173	.036	.105	.032				
.184	.074	.081	.029	.175	.036	.180	.031				
.185	.073	.083	.029	.178	.037	.111	.030				
.185	.072	.085	.028	.181	.037	.114	.030				
.186	.071	.087	.028	.183	.037	.117	.029				
.187	.071	.089	.027	.187	.039	.120	.029				
.188	.070	.091	.027	.189	.038	.123	.028				
.188	.070	.092	.026	.192	.038	.126	.028				
.189	.069	.094	.026	.194	.038	.129	.027				
.190	.069	.095	.026	.197	.038	.132	.027				
.190	.068	.097	.025	.200	.039	.135	.026				
.192	.068	.099	.025	.201	.039	.136	.026				
.192	.067	.100	.025	.202	.039	.138	.025				
.192	.067	.101	.024	.203	.039	.139	.025				
.192	.066	.102	.024	.204	.039	.141	.024				
.193	.066	.103	.024	.205	.039	.142	.024				
.193	.066	.104	.023	.206	.039	.143	.024				
.194	.066	.105	.023	.207	.040	.144	.023				
.194	.065	.106	.023	.208	.040	.145	.023				
.195	.065	.107	.023	.209	.040	.146	.023				
.195	.065	.108	.022	.209	.040	.147	.022				

ehold consists of a married couple only, married couple and children, father and children, or mother and children.

of household lives with people other than spouse or children.

: Office of Prime Minister (1961, 1966, 1971, 1976).

Other projection techniques, such as relating headship rates to gross national product, were not tried because only four data points were available (1960, 1965, 1970, and 1975) and because some factors affecting formation of households in the 1960's and early 1970's were probably unique to that period. For example, the doubling up of families in the same dwelling unit in the 1950's and 1960's was probably due to economic need as well as tradition. In the future, tradition will probably be more important as a variable explaining continued doubling of generations of the same family.

In tables 1 and 2, a nuclear household is defined as one of the following types: Married couple only, married couple and children, father and children, or mother and children. Other household is the head of the household living with people or another person other than spouse or children. The number of other households indicates the potential for movement of families sharing a single housing unit into separate living quarters.

Headship rates for nuclear, 1-person, and other households are projected separately to account for an expected divergence of trends. In general, our projections indicate that headship rates for both males and females of all age groups will increase for nuclear and 1-person households. Headship rates for both males and females of all age groups are generally expected to decline for other households, reflecting the movement of families into separate housing units.

Needed in addition to projections of headship rates to determine the number of household formations are projections for population by sex and age group.

Population Projections

Our projections of the population of Ja
by sex and age group are based on data
published by the Institute of Populatio
Problems (IPPR) of the Ministry of Heal
and Welfare (table 3). The IPPR publis
low, medium, and high estimates of
population. The data in table 3 are th
medium projections. As shown in figure
there is currently a bulge in the Japan
population in the age group of 20-40
years. By 2000, many of the people in
category will be over 50. The structure
the population by age group influences
pattern of housing starts over time; th
age group 20-40 is typically the time o
marriage and household formation in Jap

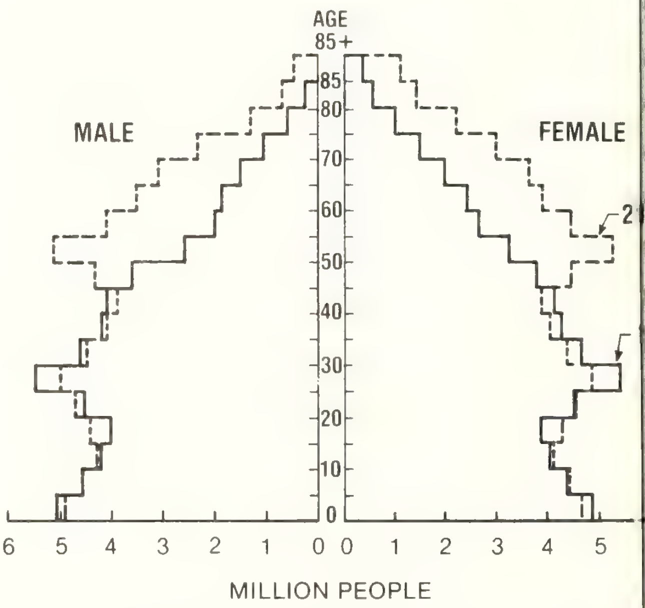

*Figure 2.--Age structure of the populat
of Japan, by sex, 1975 and 2000. (Sour
Institute of population problems (1976)*

le 3--Population of Japan, by age group, 1979-2000

(1,000 people)

ar	Age group					
	Total	20-29	30-39	40-49	50-59	60+
79	80,252	17,583	19,571	16,282	12,402	14,414
80	81,081	16,935	20,034	16,441	12,822	14,849
81	81,889	16,476	20,117	16,755	13,317	15,224
82	82,674	16,119	20,093	17,005	13,808	15,649
83	83,545	16,008	19,969	17,195	14,262	16,111
84	84,410	15,985	19,699	17,484	14,600	16,642
85	85,385	16,083	19,784	17,369	14,895	17,254
86	86,010	15,937	19,902	17,072	15,180	17,919
87	87,000	16,251	19,118	17,630	15,454	18,547
88	87,945	16,516	18,271	18,348	15,601	19,209
89	88,910	16,773	17,436	19,244	15,590	19,867
90	89,886	17,112	16,796	19,704	15,747	20,527
91	90,866	17,493	16,343	19,789	16,053	21,188
92	91,887	17,954	15,991	19,767	16,298	21,877
93	92,881	18,319	15,882	19,646	16,485	22,549
94	93,829	18,665	15,860	19,379	16,764	23,161
95	94,624	18,765	15,958	19,458	16,650	23,793
96	95,340	19,152	15,813	19,565	16,362	24,448
97	95,991	19,114	16,125	18,792	16,505	25,055
98	96,668	19,141	16,387	17,961	17,599	25,580
99	97,354	19,158	16,644	17,143	18,459	25,950
00	97,995	19,121	16,979	16,516	18,900	26,479

urce: Institute of Population Problems (1976).

The data in tables 1-5 refer to headship rates and population for people aged 20 or over. In the past two decades, there has been an increase in the number of households headed by people in the nonadult (15-19) age groups (table 6). As shown in table 6, we expect some increase in the headship rate for this group and an increase in the number of households headed by people aged 15-19. Detailed data by type of household were not available for this age group. The overall rate of attendance at high schools and colleges is still rising, and this should dampen the rate of household formation in the 15-19 age group. In our projections, we applied the headship rates from table 6 to projections of population for ages 15-19 to calculate the number of household formations for this age group.

Projections of Number of Households

We multiplied the headship rates in tables 1 and 2 by the population data in tables 3, 4, and 5 for corresponding years by sex and age group to calculate the number of adult households shown in column 1 of table 7. The basis for the number of nonadult households shown in column 2 was discussed previously. The total number of households of all types shown in column 3. The change in the number of new households is shown in column 4. In general, the projection of formation of new households shows a downward trend, reflecting in part the expected profile of the Japanese population by age group over the coming two decades.

Linkage of Number of Househo and Number of Housing Units

In Japanese surveys, if a single househol occupies a housing unit, the household is defined as a principal household. If two or more households are living together in housing unit, the owner is defined as the principal householder. If there is no owner-occupant when two or more household live together, the chief lessee is define as the principal householder. The number of principal households is thus synonymou with the number of occupied housing units The ratio of the number of principal hous holds to the number of total households (the principal household rate) increased from 1958 to 1978 (table 8). We expect this trend to continue for the next two decades. By 2000, for example, our proje tions indicate that 98.2 percent of all households will be classified as principa households. In 2000, the number of occup housing units will total 46,006,000.

As shown in table 8, the number of housin units attributable to the formation of new households declines gradually over the projection period.

e 4--Female population of Japan, by age group, 1979-2000

(1,000 people)

	Age group				
Total	20-29	30-39	40-49	50-59	60+
41,412	8,698	9,750	8,135	6,592	8,237
41,831	8,368	9,875	8,227	9,737	8,524
42,232	8,112	10,023	8,392	6,919	8,786
42,633	7,924	10,005	8,541	7,085	9,078
43,075	7,851	9,931	8,653	7,263	9,377
43,510	7,838	9,789	8,800	7,297	9,686
44,001	7,882	9,832	8,731	7,541	10,015
44,328	7,819	9,887	8,568	7,682	10,372
44,758	7,969	9,426	8,849	7,809	10,705
45,287	8,098	9,069	9,186	7,888	11,046
45,762	8,211	8,645	9,631	7,891	11,384
46,246	8,375	8,318	9,855	7,982	11,716
46,744	8,582	8,065	9,903	8,144	12,050
47,260	8,810	7,880	9,884	8,290	12,396
47,750	8,986	7,807	9,813	8,401	12,743
48,204	9,142	7,795	9,671	8,544	13,052
48,600	9,188	7,839	9,713	8,476	13,384
48,952	9,367	7,777	9,763	8,317	13,727
49,269	9,347	7,925	9,370	8,593	14,034
49,600	9,362	8,052	8,956	8,921	14,309
49,935	9,372	8,168	8,538	9,353	14,504
50,246	9,353	8,330	8,216	9,570	14,777

rce: Institute of Population Problems (1976).

Table 5--Male population of Japan, by age group, 1979-2000

(1,000 people)

Year	Age group					
	Total	20-29	30-39	40-49	50-59	60+
1979	38,840	8,885	9,821	8,147	5,810	6,177
1980	39,250	8,567	10,059	8,214	6,085	6,325
1981	39,657	8,364	10,094	8,363	6,398	6,438
1982	40,041	8,195	10,088	8,464	6,723	6,571
1983	40,470	8,157	10,038	8,542	6,999	6,734
1984	40,900	8,147	9,910	8,684	7,203	6,956
1985	41,384	8,201	9,952	8,638	7,354	7,239
1986	41,682	8,118	10,015	8,504	7,498	7,547
1987	42,242	8,282	9,692	8,781	7,645	7,842
1988	42,658	8,418	9,202	9,162	7,713	8,163
1989	43,148	8,562	8,791	9,613	7,699	8,483
1990	43,640	8,737	8,478	9,849	7,765	8,811
1991	44,122	8,911	8,278	9,886	7,909	9,138
1992	44,627	9,144	8,111	9,883	8,008	9,481
1993	45,131	9,333	8,075	9,833	8,084	9,806
1994	45,625	9,523	8,065	9,708	8,220	10,109
1995	46,024	9,577	8,119	9,745	8,174	10,409
1996	46,388	9,785	8,036	9,801	8,045	10,721
1997	46,722	9,767	8,200	9,422	8,312	11,021
1998	47,068	9,779	8,335	9,005	8,678	11,271
1999	47,419	9,786	8,476	8,605	9,106	11,446
2000	47,749	9,768	8,649	8,300	9,330	11,702

Source: Institute of Population Problems (1976).

e 6--Number of households in Japan and
ship rate for age group 15-19, selected
s, 1960-2000

Households	Headship rate
46,000	0.010
103,000	.019
211,000	.023
254,000	.032
305,000	.037
375,000	.042
446,000	.045
441,000	.047
436,000	.050

ces: Office of Prime Minister (1961,
, 1971, 1976).

Table 7--Number of households in Japan, by type, and change in number of households, 1979-2000

(In thousands)

Year	Adult (1)	Nonadult (2)	Total (3)	Change in number of new households (4)
1979	34,127	290	34,417	759
1980	34,865	305	35,170	753
1981	35,576	309	35,885	715
1982	36,268	328	36,596	711
1983	36,932	343	37,275	679
1984	37,549	361	37,910	635
1985	38,220	375	38,595	685
1986	38,734	406	39,140	545
1987	39,496	418	39,914	774
1988	40,007	432	40,439	525
1989	40,656	443	41,099	660
1990	41,255	446	41,701	602
1991	41,869	446	42,315	614
1992	42,446	441	42,887	572
1993	43,039	438	43,477	590
1994	43,587	437	44,024	547
1995	44,102	441	44,543	519
1996	44,493	446	44,939	396
1997	44,979	449	45,428	489
1998	45,442	447	45,889	461
1999	45,964	442	46,406	517
2000	46,404	436	46,840	434

Table 8--Number of ordinary households, principal household rate, and number of occupied housing units in Japan, 1958-2000, and change in number of occupied housing units, 1979-2000

Year	Ordinary households (1,000)	Principal household	Occupied units (1,000)	Year	Ordinary households (1,000)	Principal household	Occupied units (1,000)	Change numb of uni (1,00
1958	18,537	0.94034	17,431	1979	34,417	0.96434	33,190	761
1959	19,021	.94119	17,902	1980	35,170	.96519	33,946	756
1960	19,571	.94204	18,437	1981	35,885	.96604	34,666	720
1961	20,175	.94289	19,023	1982	36,596	.96689	35,384	718
1962	20,848	.94374	19,675	1983	37,275	.96774	36,073	689
1963	21,567	.94459	20,372	1984	37,910	.96859	36,719	646
1964	22,360	.94748	21,186	1985	38,595	.96944	37,416	697
1965	23,117	.95036	21,969	1986	39,140	.97029	37,977	561
1966	23,812	.95325	22,699	1987	39,914	.97114	38,762	785
1967	24,478	.95613	23,404	1988	40,439	.97199	39,306	544
1968	25,232	.95902	24,198	1989	41,099	.97284	39,983	677
1969	26,087	.96064	25,060	1990	41,701	.97369	40,604	621
1970	26,841	.96226	25,828	1991	42,315	.97454	41,238	634
1971	27,788	.96387	26,784	1992	42,887	.97359	41,832	594
1972	28,710	.96549	27,719	1993	43,477	.97624	42,444	612
1973	29,707	.96711	28,730	1994	44,024	.97709	43,015	571
1974	30,407	.96639	28,385	1995	44,543	.97794	43,560	545
1975	31,311	.96566	30,236	1996	44,939	.97879	43,986	426
1976	32,102	.96494	30,977	1997	45,428	.97964	44,503	517
1977	32,886	.96421	31,709	1998	45,889	.98049	44,994	491
1978	33,658	.96349	32,429	1999	46,406	.98134	45,540	546
				2000	46,840	.98219	46,006	466

Source: Office of Prime Minister (1959, 1961, 1964, 1966, 1969, 1971, 1974, 1976, 1979).

acancy Rates

a on vacancy rates in Japan are limited housing surveys published by the Office Prime Minister (1959, 1964, 1969, 1974, 9). These surveys classify unoccupied sing units as:

. Housing under construction; i.e., the framework has been set up, but construction has not been completed.

. Housing used temporarily; i.e., units that have no resident but are used only in the daytime or alternatively by several persons.

. Vacant housing units; i.e., where no person lives.

a for the numbers of units for each egory in the housing surveys are shown table 9. In 1978, housing under struction amounted to 0.7 percent of the al housing units; units used temporar-, 0.9 percent; vacant units, 7.6 percent; total unoccupied housing of all types unted to 9.2 percent.

jections of vacancy rates by type of sing unit are also shown in table 9. used the rationales in the following cussions to make these projections.

Housing Under Construction

The number of housing units under construction increased from 75,000 in 1958 to 258,300 in 1978, corresponding with an increase in housing starts. The number of units under construction has amounted to about 15 percent of the total number of starts in recent years, and this percentage has been relatively stable. We have assumed that the number of units under construction will continue at about 15 percent of starts over the next two decades. Since the number of starts is projected to be relatively stable and the total number of housing units is expected to increase, the ratio of units under construction to the total number of housing units is expected to decline over time, reaching 0.4 percent in 2000.

Housing Units Used Temporarily

Dwellings used temporarily include houses used only in daytime or nighttime, such as houses for security guards, or a combination store-dwelling unit where the living quarters are no longer used. We have assumed that, in the future, housing used temporarily will amount to 0.8 percent of the total number of housing units. This allows for some increase in the number of these units but also limits the rate of increase in line with recent trends.

Table 9--Vacancy rate by type of housing in Japan, for selected years, 1958-2000

(Percent of total housing units)

Year	Under construction	Used temporarily	Vacant				Total
			Total	Decrepit	Second homes	Inventory and buffer[1]	
1958	0.4	0.4	2.0	[2]	[2]	[2]	2.8
1963	.6	.4	2.5	[2]	[2]	[2]	3.5
1968	.7	.7	4.0	[2]	[2]	[2]	5.4
1973	.9	1.1	5.5	[2]	[2]	[2]	7.5
1978	.7	.9	7.6	[2]	[2]	[2]	9.2
1979	.7	.8	7.6	1.7	0.4	5.5	9.1
1980	.7	.8	7.7	1.7	.4	5.6	9.2
1981	.7	.8	7.9	1.7	.5	5.7	9.3
1982	.7	.8	8.1	1.7	.6	5.8	9.5
1983	.6	.8	8.2	1.6	.7	5.9	9.6
1984	.6	.8	8.4	1.6	.8	6.0	9.8
1985	.6	.8	8.5	1.6	.8	6.1	9.9
1986	.6	.8	8.7	1.6	.9	6.2	10.1
1987	.6	.8	8.8	1.6	.9	6.3	10.2
1988	.5	.8	8.9	1.5	1.0	6.4	10.2
1989	.5	.8	9.0	1.5	1.0	6.5	10.3
1990	.5	.8	9.1	1.5	1.1	6.5	10.4
1991	.5	.8	9.2	1.5	1.1	6.6	10.5
1992	.5	.8	9.3	1.5	1.2	6.6	10.6
1993	.4	.8	9.3	1.4	1.2	6.7	10.5
1994	.4	.8	9.4	1.4	1.3	6.7	10.6
1995	.4	.8	9.5	1.4	1.3	6.8	10.7
1996	.4	.8	9.5	1.4	1.3	6.8	10.7
1997	.4	.8	9.7	1.4	1.4	6.9	10.9
1998	.4	.8	9.7	1.4	1.4	6.9	10.9
1999	.4	.8	9.7	1.4	1.4	6.9	10.9
2000	.4	.8	9.9	1.4	1.5	7.0	11.1

[1] Number of housing units needed as inventory for real estate transactions and as a buffer for migration of regional populations.

[2] Not available.

Source: Office of Prime Minister (1959, 1964, 1969, 1974, 1979).

cant Units

number of vacant housing units increas- n 360,000 in 1958 to 2.7 million in 8. Vacant units can be classified as:

. Housing abandoned because of decrepitude or poor condition.

. Second homes, such as vacation villas and condominiums, used occasionally for business purposes.

. Housing units needed as inventory for real estate transactions and as a buffer for migration of regional populations.

r time, we expect the number of housing ts abandoned because of decrepitude to rease relative to the total number of sing units, reflecting a gradual improve- t in the quality of housing. Conse- ntly, the ratio of decrepit houses to total number of housing units is jected to decline to 1.4 by 2000.

demand for second homes is expected to rease over time, reflecting in part ng of the current population in the 40 year group. As these people grow er, financial independence will increase erest in second homes. In addition, reasing congestion in the metropolitan as will increase interest in condomin- s for occasional business use. Thus, we jected the number of second homes as a cent of the total number of housing ts to increase to 1.5 in 2000.

Vacant housing units needed as inventory for real estate transactions and as a buffer for migration of regional populations have increased in importance relative to total housing units, from 2 percent in 1958 to 5.5 percent in 1978. We expect continued increase in the proportion of housing units needed for inventory and buffer purposes, but we expect the rate of increase to slow. We project the number of units of this type expressed as a percentage of total number of housing units to increase from 5.5 percent in 1978 to 7 percent in 2000.

The vacancy rate for unoccupied housing of all types is projected to increase from 9.2 percent in 1978 to 11.1 percent in 2000.

Linkage of Vacancies and the Total Number of Housing Units

We combined the estimates of the total number of occupied housing units in table 8 with the rates of vacancy in table 9 to project the annual changes in total housing units shown in table 10. To take into account the effect of the vacancy rate on the total number of housing units, we divided the data for the total number of occupied housing units in column 1 by (100 minus vacancy rate) for corresponding years to derive estimates of the total number of housing units shown in column 2. The change in the total number of housing units attributable to formation of new households and vacancies is projected to decline from 872,000 in 1980 to 639,000 in 2000.

The net decline in housing starts attributable to household formations and vacancies is due to household formations. The number of starts attributable to vacancies generally varies between 100,000 and 200,000 throughout the projection period.

The remaining demand for new housing units is for replacement.

Table 10--Number of occupied housing units in Japan, total housing units, and changes in numbers, 1980-2000

(1,000 units)

Year	Occupied houses (1)	Total housing units (2)	Changes		
			Total (3)	New households (4)	Vacancies (5)
1980	33,946	37,385	872	756	116
1981	34,666	38,221	836	720	116
1982	35,384	39,098	877	718	159
1983	36,073	39,904	806	689	117
1984	36,719	40,708	804	646	158
1985	37,416	41,527	819	697	122
1986	37,977	42,244	717	561	156
1987	38,762	43,165	921	785	136
1988	39,306	43,771	606	544	62
1989	39,983	44,547	803	677	126
1990	40,604	45,317	743	621	122
1991	41,238	46,076	759	634	125
1992	41,832	46,792	716	594	122
1993	42,444	47,423	631	612	19
1994	43,015	48,115	692	571	121
1995	43,560	48,779	664	545	119
1996	43,986	49,256	477	426	31
1997	44,503	49,947	691	517	174
1998	44,994	50,498	551	491	60
1999	45,540	51,111	613	546	67
2000	46,006	51,750	639	466	173

emand for Replacement ousing

shown in table 11, the ratio of removals
the total number of housing units
ressed as a percentage varied over the
iod 1961-77 from a low of 1.4 in 1965 to
igh of 2.94 in 1970. The total number
annual removals generally increased to a
k of 856,000 in 1972; since then, the
ber has fluctuated. The potential impor-
ce of removals in estimating future
and for housing is indicated by compari-
of historical data for removals and
sing starts; for example, in 1973, the
k year for housing starts in Japan,
and for replacement amounted to about 45
cent of new starts.

and for replacement housing is tied in
t to economic conditions in Japan. The
e in the number of removals in the late
0's and early 1970's corresponds with
ing standards of living and rapid rates
economic growth. The drop in demand for
lacement in 1974 and 1975 corresponds
h a recessionary period. In the late
0's and early 1970's, housing units that
e replaced were made up in large part of
-quality units constructed in the 10
rs after World War II.

Table 11--Number of housing units in Japan, removals, and percent removed, 1961-77

Year	Housing units (1,000)	Housing units removed (1,000)	Percent removed
1961	19,644	363	1.85
1962	20,342	333	1.65
1963	21,090	403	1.91
1964	21,984	392	1.78
1965	22,937	320	1.40
1966	23,798	382	1.61
1967	24,644	531	2.15
1968	25,591	652	2.55
1969	26,580	708	2.66
1970	27,553	809	2.94
1971	28,701	521	1.82
1972	29,834	856	2.87
1973	31,059	851	2.74
1974	31,947	533	1.67
1975	32,915	483	1.47
1976	33,858	672	1.98
1977	34,784	657	1.89

Source: Based on data from Office of Prime Minister (1959, 1964, 1969, 1974, 1979).

A key in estimating demand for replacement to the year 2000 is to estimate how long houses built in the last two decades will last. From 1961 to 1977, the number of housing units in Japan increased by 77 percent. There are examples of houses in Japan lasting over 100 years. There are also examples of houses lasting fewer than 10 years. Available inventory data on the age of housing suggests that housing built in the 1960's and 1970's has gradually increased in quality and more years of service are expected before removal.

A second key in estimating future demand for replacement is the linkage between economic conditions and replacement demand; historical data suggest this type of linkage. We considered the historical relationship not appropriate for long-term projections, however. The gross national product of Japan will undoubtedly continue to increase over the next two decades, indicating rising demands for replacement housing. The quality of the housing units will probably be continually upgraded over time, however, and this will temper demand for replacement.

There seems little doubt that gross national product and other measures of economic growth will continue to increase in Japan, but there is much uncertainty about the rate of increase. Because of this uncertainty, we have projected low, medium, and high estimates of the ratio o removals to the total number of housing units (table 12). These estimates correspond with low, medium, and high estimates of economic growth. The three trends of ratio of the removal to the tot number of housing units have been project on a judgmental basis. No quantitative linkages among removals, housing units, a economic conditions were explicitly consi ered. The size of the ratio for the low projection corresponds roughly with the size of the ratio in the 1974-75 period, the medium projection is roughly a contin tion of the trend for 1976-79, and the si of the ratio for the high projection corr sponds roughly with the size of the ratic in the late 1960's and early 1970's.

All three trends have built into them an increase in the ratio of removals to total number of housing units in the early 1980 This reflects our judgment that some repl ment demand has probably built up in the years since the 1974-75 recession. The economy in Japan has been slow to recover from the recession, undoubtedly thwarting some replacement demand. After 1984, we expect the ratio of removals to total number of housing units to decline gradua to 2000 for all three projections, reflec ing an assumed gradual improvement in the quality of the housing units. Marcin (19 found considerable variation in U.S. replacement demand over time.

le 12--Replacement rates and number of housing units in Japan
aced by high, medium, and low rates of economic growth,
)-2000

	Replacement rate, by rate of economic growth			Number of units (1.000), by rate of economic growth		
	High	Medium	Low	High	Medium	Low
0	2.10	2.00	1.90	785	748	710
1	2.19	2.07	1.95	837	791	745
2	2.30	2.15	2.00	899	841	782
3	2.30	2.15	2.00	918	858	798
4	2.30	2.15	2.00	936	875	814
5	2.28	2.12	1.95	947	880	810
6	2.26	2.09	1.90	955	883	803
7	2.24	2.06	1.87	976	889	807
8	2.22	2.03	1.83	972	875	801
9	2.21	2.00	1.78	984	891	793
0	2.19	1.97	1.74	992	893	789
1	2.17	1.94	1.70	1,000	894	783
2	2.15	1.91	1.66	1.006	894	777
3	2.13	1.88	1.62	1,010	892	768
4	2.11	1.85	1.58	1,015	890	760
5	2.09	1.82	1.54	1,019	888	751
6	2.07	1.79	1.50	1,020	882	739
7	2.06	1.76	1.45	1,029	879	724
8	2.04	1.73	1.41	1,030	874	712
9	2.02	1.70	1.37	1,032	869	700
0	2.00	1.67	1.33	1,035	864	688

We multiplied the replacement rates in table 12 by the estimates for housing units in table 10 for corresponding years to generate the number of housing starts attributable to housing units replaced shown in the last three columns of table 12. Under the low projection, the total number of housing units demanded in the form of replacements would generally be between 700,000 and 800,000 for each year of the projection period. For the medium projection, replacement demand would amount to 800,000 to 900,000 units per year; and for the high projection, from about 800,000 to over 1,000,000 units by 2000.

Even under the low projection, the number of housing units attributable to replacement demand is almost the same as in 1969, 1970, 1972, and 1973--peak years by historical standards. This occurs despite a relatively low, declining ratio of removals to total number of housing units. The number of housing units is continuously increasing over time, accounting for this apparent anomaly. We again emphasize that there are few data available to judge how long houses built in Japan since the 1950's will last. If these houses are durable--lasting 25 or more years on the average--the replacement demands shown in table 12 are probably too high.

Summary of Projections o Housing Starts

As shown in table 13, projections of to housing starts depend on what is assume about the rate of replacement of housin units. Under a high rate of removal, housing starts increase from current le to a peak of 1,795,000 units in 1987 an then decline to about current levels by 2000. For a medium rate of removal, housing starts initially increase to a of 1,708,000 in 1987 and then decline b current levels in 2000. For a low rate removal, housing starts stay near curre levels until the early 1990's and then decline to 1,289,000 units in 2000. Kee in mind that we have arbitrarily assume replacement demand to be somewhat highe the early 1980's in light of probably pent-up demand for replacement that has developed since the 1974-75 recession.

e 13--Number of housing starts in Japan by source of demand

(1,000 units)

r	Source of demand								
	Formation of new households	Vacancies	Removals, by rate of economic growth			Total, by rate of economic growth			
			High	Medium	Low	High	Medium	Low
0	756	116	785	748	710	1,652	1,605	1,577
1	720	116	837	791	745	1,676	1,630	1,584
2	718	159	899	841	782	1,761	1,703	1,644
3	689	117	918	858	798	1,758	1,698	1,638
4	646	158	936	875	814	1,765	1,704	1,643
5	697	122	947	880	810	1,757	1,690	1,620
6	561	156	955	883	803	1,735	1,663	1,583
7	785	136	976	889	807	1,795	1,708	1,626
8	544	62	972	875	801	1,720	1,623	1,549
9	677	126	984	891	793	1,761	1,668	1,570
0	621	122	992	893	789	1,709	1,610	1,506
1	634	125	1,000	894	783	1,768	1,662	1,551
2	594	122	1,006	894	777	1,745	1,633	1,516
3	612	19	1,010	892	768	1,712	1,594	1,470
4	571	121	1,015	890	760	1,695	1,570	1,440
5	545	119	1,019	888	751	1,681	1,550	1,413
6	426	51	1,020	882	739	1,631	1,493	1,350
7	517	174	1,029	879	724	1,640	1,490	1,335
8	491	60	1,030	874	712	1,603	1,447	1,285
9	546	67	1,032	869	700	1,650	1,487	1,318
00	466	173	1,035	864	688	1,636	1,465	1,289

Replacement demand under a low rate of removal generally accounts for about one-half of total housing starts. Under a high rate of removal, replacement demand accounts for over 60 percent of total housing starts by 2000. Of the three types of housing demand discussed in this report--formation of new households, vacancies, and replacements--we feel less confident about our projections of replacement demand. The projections of new household formation are based on the demographic characteristics of the population in Japan. The detailed historical information available for headship rates by sex and age group, along with population projections by sex and age group, provide a reasonable basis for projecting formation of new households. Sharp shifts in demographic patterns are probably not likely. Vacancy rates are factors determining new housing starts, but their influence is relatively small compared with new household formation and replacement demand. Errors in the projection of vacancy rates would not have much effect on projections of housing starts.

Historical data on removals of housing units in Japan reflect the post-World War II experience in upgrading substandard housing constructed in the decade following the war. Removal rates exceeded 2 percent in the late 1960's and early 1970's. By contrast, Marcin (1977) estimated the removal rate for the United States to be 1 percent or less. Our projections of removals in Japan are based in part on historical data, possibly causing an upward bias on our estimates of removal demands for all three projections. As discussed in the next section, however, the desire to upgrade housing is evident in the gradual increase in the average size of housing units. This desire to continually upgrade housing may result in demands for replacement housing occurring as we project.

Regardless of whether removals are ass to occur at low, medium, or high level our projections indicate that the peri rapid increase in the number of housin starts in Japan is over. Even under t assumption of relatively high rates of economic growth, housing starts never exceed 1.8 million units in any year t 2000. If, as expected, future rates o economic growth are relatively low by standards of the 1960's and early 1970 housing starts will stay near current levels and may decline. Thus, the Japa market for imported construction mater over the next two decades will likely much different than for the past two decades. Rather than experiencing increased sales because of rising dema producers in competing supply areas generally will be able to increase sal only by displacing the construction materials of competing suppliers.

Demands for imported wood construction materials for the home building indust Japan will be affected by the average of new housing units and by the amount wood consumed per housing unit.

verage Size of ousing Units

e average floorspace per new housing art in Japan increased from 58.9 square ters (633.8 square feet) in 1965 to 84.1 04.9 square feet) in 1977 (table 14). e average was somewhat higher for wooden using than for nonwooden housing. In neral, wooden housing consists of single mily detached units, and nonwooden using consists of high-rise apartments. e increase in average floorspace doubtedly contributed to the rise in mand for imported construction materials ring this period. We have assumed that e historical trend in increasing oorspace will continue into the future both wooden and nonwooden housing. By 00, the average floorspace for new using would exceed 100 square meters ,076 square feet) by our projections.

The volume of wood consumed per housing unit is influenced by the type of construction. The proportion of total housing starts made up of wooden housing decreased from 0.767 in 1965 to 0.641 in 1977 (table 15). The decline in this proportion was undoubtedly due to a combination of factors, including migration of the population from rural to urban areas, and an increase in land prices that inhibited construction of detached housing for a single family. Primarily because land prices are expected to continue to increase and because of increasing congestion in the metropolitan areas, we projected the number of wooden housing starts as a proportion of total starts to continue to decline in the future, reaching 0.55 in 2000.

le 14--Average floorspace per new housing unit in an, by type of housing, for selected years, 55-2000

(In square meters[1/])

r	All housing units	Housing unit	
		Wooden	Nonwooden
5	58.9	58.9	58.9
6	62.9	63.2	62.0
7	66.8	66.6	67.2
8	65.9	66.4	64.5
9	66.9	67.6	65.1
0	68.1	68.5	66.9
1	69.4	71.3	66.4
2	71.2	73.1	68.3
3	76.9	79.9	72.7
4	81.5	84.8	75.0
5	82.9	85.5	77.6
6	82.2	85.5	76.0
7	84.1	87.0	78.9
30	87.0	90.0	82.0
35	92.4	96.0	87.0
90	96.7	101.0	91.0
95	101.1	106.0	95.0
00	104.8	110.0	99.0

urce: Office of Prime Minister (1978).

1 square meter = 10.76 square feet.

Table 15--Number of housing starts in Japan, percent wooden housing, and percent nonwooden housing, for selected years, 1965-2000

Year	Housing starts (1,000)	Housing units	
		Wooden	Nonwooden
		- - -Percent- - -	
1965	843	76.7	23.3
1966	857	74.9	25.1
1967	991	76.5	23.5
1968	1,202	73.7	26.3
1969	1,347	71.3	28.7
1970	1,485	69.8	30.2
1971	1,464	66.1	33.9
1972	1,808	61.5	38.5
1973	1,905	58.8	41.2
1974	1,316	66.1	33.9
1975	1,356	66.9	33.1
1976	1,524	65.2	34.8
1977	1,508	64.1	35.9
1980	1,529	63.0	37.0
1985	1,610	60.0	40.0
1990	1,533	58.0	42.0
1995	1,476	56.0	44.0
2000	1,395	55.0	45.0

Source: Office of Prime Minister (1978).

Wood Consumed Per Housing Unit

We could find no detailed historical data for wood consumption by type of housing. A report by the Association of Southeast Asian Nations (1977) indicated that the number of cubic meters of sawn wood consumed per square meter of floorspace declined from 0.31 in the 1965-67 period to 0.21 in 1973. Other, fragmentary information obtained through the Forestry Agency of Japan also suggests that the volume of lumber consumed per unit of floorspace has declined for housing of all types (table 16), but not by as much as indicated in the Association report.

Table 16--Volume of lumber used per unit of floorspace in Japan, for selected years, 1965-75
(Cubic meters per square meter)

Year	Type of housing			
	Wooden	Ferro concrete	Steel frame	Ferro concrete and steel frame
1965	0.215	0.097	0.048	0.073
1970	.197	.091	.044	.068
1975	.192	.087	.042	.065

Source: Ueda, Michihiko. 1979. Japanese long-term housing outlook (1979-2000). 129 p., illus. State Wash. Dep. Nat. Resour. Olympia.

The volume of lumber consumed per unit o floorspace has probably decreased becaus of some substitution of metals, plywood, glass, etc., for lumber and because of increasing floorspace per unit of housin For example, the area of walls does not increase as rapidly as does the floor ar Unless there is a major shift in constru tion techniques that we do not foresee, volume of lumber consumed per unit of floorspace--the lumber usage rate--will probably not change much over the next t decades. If anything, the lumber usage rate will probably continue to decline gradually over time, reflecting our assu tion that the average floorspace per housing unit will increase.

Lumber consumption and the demand for imported construction materials have bee affected by four factors in the 1960's a 1970's: An increase in the number of housing starts, a decrease in the ratio the number of wooden housing units to to housing starts, an increase in floorspace housing unit, and a decline in the volum of lumber consumed per unit of floorspac We expect the decrease in the proportion wooden housing starts and the decrease i the lumber usage rate to continue. In addition, we expect average floorspace p housing unit to continue to increase. T only factor that deviates from past tren in our projections is the expectation of relatively stable to declining number of housing starts.

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Housing demand in Japan is analyzed in terms of new household formations, vacancies, and replacements of housing stock. Total number of starts is projected to stay near current levels or decline, depending on assumptions about replacement demands. This contrasts with rapid growth in number of starts during the 1960's and early 1970's.

Keywords: Housing starts, trading policy (international), import/export (forest products), Japan.

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Forest Service

Pacific Northwest
Forest and Range
Experiment Station

Research Paper
PNW-277

November 1980

The Impact of the Export and Import of Raw Logs on Domestic Timber Supplies and Prices

David R. Darr,
Richard W. Haynes,
and Darius M. Adams

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The Impact of the Export and Import of Raw Logs on Domestic Timber Supplies and Prices

Reference Abstract

Orr, David R., Richard W. Haynes, and Darius M. Adams.
1980. The impact of the export and import of raw logs on domestic timber supplies and prices. USDA Forest Service Research Paper PNW-277, 38 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Reviews U.S. foreign and domestic markets for softwood construction materials, giving special consideration to trade patterns among Japan, Canada, and the United States. For alternative assumptions about market responses to a ban of U.S. softwood log exports, displays impacts on selected measures of U.S. softwood stumpage, lumber, and plywood markets.

KEYWORDS: Import/export (forest products), markets (internal), trade policy, supply/demand (forest products).

Research Summary
Research Paper PNW-277
1980

Softwood-log exports from the United States grew ten-fold between the early 1960's and the mid-1970's. Shifts in variables driving the U.S. domestic market during this period mask any effect of log exports on domestic timber supplies and prices.

The impacts of a ban on U.S. softwood-log exports on domestic timber supplies and prices would depend in part on the responses of Japan in attempting to replace the equivalent of the construction materials that would have been recovered from U.S. logs. The impacts of a ban would also tend to depend in part on the responses of U.S. stumpage owners and timber processors to the change in market opportunities. These responses are not known with certainty. The effects of log exports upon supplies and prices of domestic timber were simulated under alternative assumptions about the responses of Japanese importers and consumers and of U.S. stumpage owners and timber processors to a ban on softwood-log exports. The analytical model simulated market interactions among U.S. and Canadian softwood-supply regions to changes in offshore markets and to changes in the availability of stumpage, lumber, and plywood in each region.

Domestic market forces will continue to result in rising real prices for softwo lumber and plywood in the United States during the 1980's. A ban on softwood-lo exports would tend to contribute to eve higher prices, unless lumber-processing capacity expanded significantly on the coast and unless Japan turned to source construction materials other than North America. Prices and U.S. consumption of softwood lumber in the 1980's would be changed less than 2 percent by a ban on softwood-log exports, with the directio change contingent on market responses i Japan and in the log-exporting regions. Prices of softwood plywood would genera decline by less than 4 percent and consumption would increase by less than 4 percent.

A ban on log exports would reduce stump prices in the log-exporting regions, wi the size of the decrease contingent on ket responses in Japan and on the exten construction of new processing capacity ban would adversely affect stumpage own public and private--in the log-exportin regions and enhance the competitive pos tions of timber processors in these reg relative to processors in other U.S. an Canadian regions.

reface

is report contains:

discussion of trends in U.S. imports
nd exports of logs and the development
f the log-export issue.

discussion of possible future trade
atterns, market interactions, and their
mplications for efforts at evaluation of
he impact of the import and export of
aw logs upon domestic timber supplies
nd prices.

sensitivity analysis of the potential
mpacts of a ban on softwood-log exports
nder alternative sets of assumptions
bout market responses to the change in
rade policy. The sensitivity analysis is
ased on five scenarios or sets of as-
umptions about market responses. Under
cenario 1, we assumed that Japan would
urchase from the United States the lumber
quivalent of log-export volume that would
ave been exported and that Canada would
ot expand sales of softwood lumber to
apan. Under scenario 2, we assumed that
apan would somehow turn to sources of
onstruction materials other than North
merica. Under scenario 3, we assumed that
apan would purchase from Canada the
umber equivalent of U.S. log-export
olume and that U.S. exports of softwood
umber would not increase. Under scenario
, we assumed that Japan would purchase
rom the United States the lumber equiva-
ent of log-export volume, that Canadian
ales to Japan would not expand, and that
umber-processing capacity would not
xpand in the Douglas-fir region. Under
cenario 5, we assumed that Japan would
urchase from the United States half the
umber equivalent of log-export volume
nd half from Canada.

For each scenario, we display for the period 1980 to 1990, the effect of a ban on log exports on prices, production, consumption, and trade in softwood lumber and plywood, the U.S. balance of trade in timber products, softwood-stumpage prices, and softwood-timber harvest.

By design, we make no recommendation about what log-export policy should be. Our intent in this report is to help provide a basis for understanding how log exports might influence supplies and prices of domestic timber and for placing a range on the size of these influences.

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Background

he impact of the export and import of raw ogs upon domestic timber supplies and rices has developed as an issue over the ast 15 years. The issue has centered on og exports, which increased in volume from bout 300 million board feet per year in he early 1960's to over 3 billion board eet per year in the 1970's. During this eriod, log imports have generally been ess than 100 million board feet per year nd have not been a national issue.

he log-export issue rests not only on the istribution of gains and losses from the hange in market patterns initiated through rowth of the market, but also on the lack f agreement about the size of gains and osses. We do not know how much the export f raw logs has affected domestic timber upplies and prices nor how much domestic imber supplies and prices would be affected f trade policies were changed so as to lter market patterns.

n past market patterns, what would have appened in the absence of growth of the og-export market is not clear. Other ariables potentially affecting prices and imber supplies during this time include rowth in U.S. housing starts to over 2 illion per year in the early 1970's, rapid rowth in softwood-lumber imports from anada, and the emergence of the softwood-lywood industry in the South as a major egment of the industry.

Similarly, in the changing of trade policies to alter market patterns, what would happen to domestic and foreign timber markets in the absence of log-export sales is not clear. Foreign demands for softwood construction materials would continue even if log exports were not permitted. In the absence of precedent, identifying potential impacts of a change in trade policies on supplies and prices of domestic timber must rest on a set of assumptions about market responses expected after the change in policy. Interest groups potentially affected by a change in log-export policy have not agreed. This lack of agreement will probably continue leading to a continuation of the debate over policies affecting log trade.

Although market reactions to a change in log-export policies cannot be predicted with precision, alternative reactions can be postulated and their implications on supply and demand of domestic timber assessed. This "sensitivity analysis" approach does not resolve the export issue analytically, but it does establish a possible range for the magnitude of the effects of log exports on supplies and prices of domestic timber.

The log-export trade cannot be viewed in isolation from trade in other commodities, especially softwood lumber. A shift in U.S. log-export policy would probably cause significant shifts in patterns of world trade in softwood lumber. A shift in U.S. log-export policy could also affect the supply of raw material available to the U.S. softwood-plywood industry. Although the emphasis in this report is on softwood-log exports, the softwood-lumber and softwood-plywood industries are brought into the discussion as appropriate.

The report also includes:

- A discussion of trends in U.S. imports and exports of logs and the development of the log-export issue.
- A discussion of possible future trade patterns, market interactions, and their implications for efforts at evaluation of the impact of the import and export of raw logs upon supplies and prices of domestic timber.
- A sensitivity analysis of the potential impacts of a ban on softwood-log exports under alternative sets of assumptions about market responses to the change in trade policy.

Our intent is to help provide a basis for understanding how log exports might influence supplies and prices of domestic timber and for placing a range about the size of these influences.

Trends in Log Exports and Imports

The United States became a net exporter logs in the late 1950's (fig. 1). Log-ex rt volume increased from 10 million cubic f t (64 million board feet) per year in the early 1950's to a cyclical high of 515 mi- lion feet (3.2 billion board feet) in 19 . After dropping in 1974 in response to a worldwide recession, log-export volume increased to another cyclical high of 51 million cubic feet (3.2 billion board fe) in 1976. Volume declined in 1977 but recovered in 1978 to 515 million cubic f t (3.2 billion board feet).

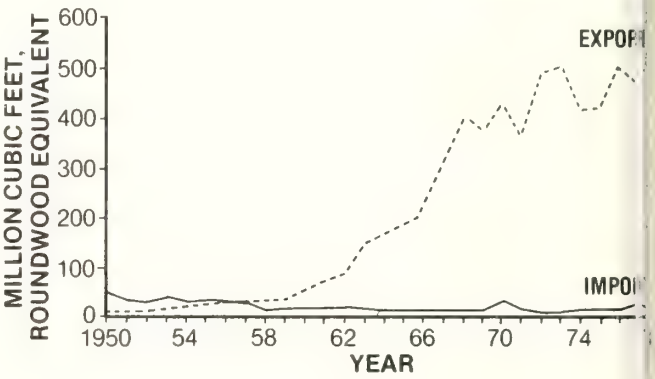


Figure 1.--Imports and exports of logs for the United States, 1950-78. Source: Phelps (1977).

In contrast to the rise in log-export vo me over the past 25 years, the annual volum of log imports has declined from about 4 million cubic feet (224 million board fee per year in the 1950's to about 15 milli cubic feet (81 million board feet) per ye in the 1970's.

Over the past two decades, U.S. log expo s have become increasingly dominated by sof - wood species (table 1). In the mid-1970' softwoods accounted for over 95 percent c total export volume. Japan is the major customer for U.S. log exports, accounting for about 82 percent of the total (table . Canada, the second largest customer, take about 11 percent.

able 1--U.S. exports of logs, 1950-78 (Million oard feet, log scale)

Year	Softwoods	Hardwoods	Total
1950	28.9	19.3	48.2
1951	57.9	21.5	79.4
1952	44.4	19.2	63.7
1953	86.0	29.2	115.1
1954	106.4	33.1	139.5
1955	144.2	22.0	166.2
1956	154.9	32.8	187.7
1957	107.3	32.0	139.3
1958	127.3	42.5	169.8
1959	167.6	37.0	204.6
1960	210.3	56.0	266.3
1961	432.2	49.5	481.8
1962	452.7	69.5	522.2
1963	879.6	71.8	951.3
1964	1,022.6	63.7	1,086.3
1965	1,111.4	81.4	1,192.8
1966	1,317.5	75.6	1,393.1
1967	1,873.6	97.1	1,970.7
1968	2,473.2	94.9	2,568.1
1969	2,316.8	80.2	2,379.0
1970	2,684.1	68.9	2,753.0
1971	2,233.4	59.0	2,292.4
1972	3,049.4	93.9	3,143.3
1973	3,107.2	114.4	3,221.6
1974	2,523.7	118.7	2,642.4
1975	2,600.6	66.3	2,626.5
1976	3,155.7	94.3	3,249.9
1977	2,980.0	100.1	3,080.1
1978	3,298.4	110.8	3,409.2

Source: Phelps (1977).

o clear pattern appears for the species omposition of U.S. log imports (table 3). anada is the dominant supplier and enerally accounts for over half of the nnual volume of imports (table 4).

n the mid-1970's, log exports amounted to bout 4 percent of the total volume of wood onsumed in the United States for lumber, lywood, and veneer production. The corresponding figure for log imports was less han 0.2 percent.

Table 2--U.S. exports of logs by major region of destination, 1950-78 (Million board feet, log scale)

Year	Canada	Western Europe	Japan	Other	Total
1950	42.5	3.6	--	2.1	48.2
1951	71.8	4.7	1.4	1.6	79.4
1952	53.8	3.0	6.5	.4	63.7
1953	69.2	3.8	41.6	.6	115.1
1954	75.4	4.8	54.5	4.7	139.5
1955	138.4	8.9	18.0	.8	166.2
1956	160.2	5.7	20.5	1.2	187.7
1957	97.1	5.3	36.0	1.0	139.3
1958	112.6	7.7	47.9	1.6	169.8
1959	126.6	7.2	70.1	.7	204.6
1960	150.7	15.9	98.6	1.1	266.3
1961	99.6	16.3	364.8	1.1	481.8
1962	167.3	24.8	329.0	1.2	522.2
1963	209.3	32.2	691.1	18.8	951.3
1964	288.5	19.0	755.4	23.4	1,086.3
1965	352.9	29.4	804.4	6.2	1,192.8
1966	266.2	17.3	1,083.0	26.5	1,393.1
1967	335.8	20.8	1,583.6	30.6	1,970.7
1968	341.8	28.8	2,119.2	78.4	2,568.1
1969	324.6	29.9	2,007.8	34.8	2,397.0
1970	291.8	23.6	2,377.3	60.3	2,753.2
1971	343.6	20.8	1,847.1	80.9	2,292.4
1972	519.1	31.9	2,529.9	62.4	3,143.3
1973	417.8	42.0	2,634.7	127.1	3,221.6
1974	332.3	39.1	2,114.2	156.7	2,642.4
1975	277.6	35.3	2,256.4	97.6	2,666.9
1976	362.5	48.6	2,675.1	163.7	3,249.9
1977	350.0	48.0	2,470.5	211.6	3,080.1
1978	368.4	56.4	2,646.1	338.3	3,409.2

Source: Phelps (1977).

Through an increase in volume and an increase in average value, log exports have gained an increasing share of the total value of U.S. exports of timber products, going from 7 percent in the early 1960's to 21 percent in the mid-1970's (fig. 2). The average value of log exports increased steadily during the late 1960's and jumped in 1972-73 (fig. 3). The sharp increase in average value in 1972 resulted from a combination of factors, including devaluation of the U.S. dollar relative to the Japanese yen and an unprecedented number of housing starts in both Japan and the United States. Average prices held up well even during the decline in demand in 1974-75. Devaluation of the dollar relative to yen contributed to upward pressure on prices during 1977 and 1978. In general, the total value of exports of all timber products has increased, but the value of log exports has increased faster.

Table 3--U.S. imports of logs 1950-78 (Million board feet, log scale)

Year	Softwoods	Hardwoods	Total
1950	156.5	111.9	268.5
1951	84.8	127.2	212.0
1952	113.8	77.1	190.8
1953	115.5	111.6	227.1
1954	128.2	92.6	220.9
1955	79.4	119.3	198.8
1956	39.7	120.6	160.3
1957	40.5	90.9	131.3
1958	21.6	73.8	95.3
1959	25.4	72.8	98.2
1960	32.3	80.2	112.5
1961	57.1	48.6	105.7
1962	38.1	62.1	100.1
1963	44.1	53.9	97.9
1964	8.7	56.3	65.1
1965	13.5	54.6	68.1
1966	42.5	53.1	95.6
1967	33.9	43.1	76.9
1968	39.4	45.9	85.3
1969	41.7	40.2	81.8
1970	106.5	37.9	144.4
1971	55.7	28.3	84.0
1972	11.3	28.0	39.3
1973	8.5	25.0	33.5
1974	45.6	31.0	76.6
1975	68.5	17.0	85.5
1976	67.4	14.2	81.6
1977	139.5	15.0	154.5
1978	79.1	17.8	96.9

Source: Phelps (1977).

Table 4--U.S. imports of logs by major reg of origin, 1950-78 (Million board feet, lo scale)

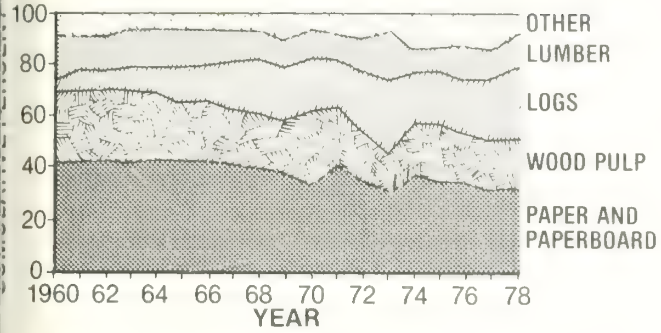
Year	Canada	Other	Total
1950	173.0	95.5	268.5
1951	104.0	108.0	212.0
1952	127.0	63.8	190.8
1953	132.5	94.6	227.1
1954	139.1	81.8	220.9
1955	92.0	106.8	198.8
1956	52.8	107.5	160.3
1957	49.1	82.2	131.3
1958	27.7	67.6	95.3
1959	31.9	66.3	98.2
1960	39.2	73.3	112.5
1961	62.5	43.2	105.7
1962	42.6	57.5	100.1
1963	51.5	46.4	97.9
1964	18.1	47.0	65.1
1965	20.3	47.8	68.1
1966	49.4	46.2	95.6
1967	40.6	36.3	76.9
1968	46.2	39.1	85.3
1969	49.5	32.3	81.3
1970	114.9	29.5	144.4
1971	64.6	19.4	84.0
1972	17.3	22.0	39.3
1973	17.8	15.7	33.5
1974	57.0	19.6	76.6
1975	80.3	5.2	85.5
1976	78.0	3.6	81.6
1977	150.5	4.0	154.5
1978	85.9	11.0	96.9

Source: Phelps (1977).

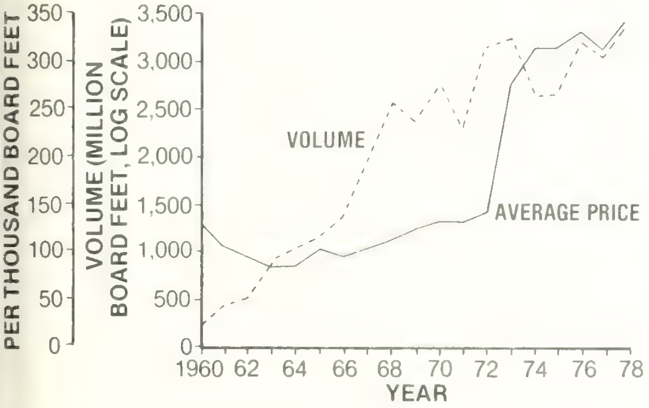
Despite an increase in average price, lo imports have accounted for a decreasing share of the total value of U.S. imports of timber products, going from 1.5 percent i the 1960's to less than 1 percent in the mid-1970's.

In 1978, logs accounted for 0.8 percent the value of all U.S. commodity exports, and log imports amounted to less than 0.1 percent of the value of all commodity imports.

Focus of Interest in Log Trade



igure 2.--Cumulative percentage dis-ribution of United States exports of imber products, by product, 1960-78. ource: Phelps (1977).



'igure 3.--Average value and total volume of United States log exports 1960-78. ource: Phelps (1977).

Interest in softwood-log exports has been concentrated on trade from the U.S. west coast to Japan. By the mid-1970's, softwood-log exports from the west coast accounted for over 85 percent of total U.S. log-export volume. During the 1970's, the volume of softwood-log export from the west coast became increasingly dominated by shipments from Washington and Oregon, which account for over 95 percent of the total. Exports from northern California peaked at 212 million board feet in 1968 and, since that time, shipments have generally been between 75 and 100 million board feet per year. Softwood-log exports from Alaska have rarely exceeded 50 million board feet per year.

In the four west coast States, export of roundwood is prohibited from Federal and State lands, with the exception of lands managed by the State of Washington Department of Natural Resources (DNR) (Lindell 1978). In addition, export from private lands is subject to limitation if the log exporter also purchases Federal timber. British Columbia has restricted roundwood-log export since 1906. Only volume declared surplus to domestic need can be exported. About 73 percent of the log export from Washington and Oregon originates on private land and 20 percent on DNR land.

During the decade-long debate over policy on softwood-log export, several public hearings have been held, e.g., United States Senate Committee on Banking, Housing, and Urban Affairs (1973). The hearing records are the best available source on the positions of organizations and individuals that participated in the debate. These positions have changed little over time.

The potential for log export to affect local communities is concentrated in the Puget Sound, Aberdeen, and Longview areas of the State of Washington, and the Astoria, Coos Bay, and Portland areas of the State of Oregon. In 1978, for example, Puget Sound ports accounted for 46.8 percent of total volume of log export from the west coast of 3 billion board feet. The percentage exported from each area is as follows (Ruderman 1979):

Washington	
Puget Sound	
Tacoma	18.7
Port Angeles	13.0
Everett	10.8
Olympia	2.9
Anacortes and Bellingham	1.4
Total	46.8
Aberdeen	17.1
Longview	10.9
Other	.2
Total	75.0
Oregon	
Portland	9.3
Astoria	5.6
Coos Bay	4.9
Other	.5
Total	20.3
Northern California	2.4
Alaska	2.3
Total	100.0

Any shift in trade policy for softwood logs vould directly affect these areas. As dis-ussed later, market interactions tend to issipate the effects of a change in trade olicy when impacts are considered egionally and nationally.

upplies and prices of domestic timber are nly two of the concerns that have been aised in public discussions of policy on oftwood-log export. Other concerns are iscussed in Hamilton (1971) and Darr 1975, 1977).

Future Trade Prospects and Market Interactions

Domestic and foreign demands for softwood logs, lumber and plywood interacting with domestic and foreign supplies of these products have the most potential for affecting the price and availability of softwood construction materials in the United States. Developments in hardwood and fiber-based markets affect markets for softwood construction materials, but only indirectly. The characteristics of these supplies and demands vary among countries and by type of product. The purpose of the following review of domestic and foreign demands and supplies for softwood construction materials is to discuss likely trade patterns without a change in U.S. log-export policy. In addition, we point out the types of interactions that would determine market responses to a change in policy.

Demand

Domestic

In the U.S. domestic market, new housing accounts for about one-third of the lumber and plywood used (table 5). When residential upkeep and improvements and new nonresidential construction are added to the volumes used in new housing, the portion of lumber and plywood consumption attributable to construction rises to over 50 percent.

Of the primary uses for lumber and plywood, new housing tends to be especially cyclical. These cycles are driven in part by the availability of mortgage money, interest rates, and personal income.

ble 5--Lumber and plywood consumption by major end use
the United States, 1970

End use	Lumber	Plywood
	Million board feet)	Million square feet, 3/8-inch basis)
w housing	12,270	6,330
sidential upkeep and improvements	4,690	2,510
w nonresidential construction	3,690	1,700
nufacturing	4,670	1,656
ipping	5,720	1/
her	8,460	5,626
tal	39,500	17,822

Not available.

ource: USDA Forest Service (1973).

ycles in housing starts and other end uses or lumber and plywood are reflected in ycles in lumber and plywood prices. Changes n end-product prices resulting from changes n demand are transmitted back to the timber-esource base to interact with timber suplies to determine timber prices. Average rices of softwood lumber have changed by s much as 28 percent from one year to the ext, softwood plywood by 25 percent, and tumpage prices in the Pacific Northwest, 3 percent. These cycles will probably ontinue.

he wood-pulp industry is becoming ncreasingly important in determining imber prices in the United States. For xample, pulp products accounted for 20 ercent of the timber used in the United tates in the early 1950's and 34 percent n the mid-1970's (Phelps 1977).

vailable information indicates a coninuation of strong domestic markets for imber products in the United States over he coming decades. For example, the emographic characteristics of the popuation suggest that the demand for new ousing units might exceed 2 million per ear over the next decade (Marcin 1977).

Coincident with the projection of strong markets for timber products in the United States is an expected continuation of the rise in prices for these products. For example, lumber prices historically have risen at an annual rate of about 1.5 percent relative to prices in general, and substantial increases are expected in the future (USDA Forest Service 1979).

Foreign

Foreign demand for U.S. softwood lumber was relatively stable until the late 1960's and early 1970's (table 6). Softwood-lumber exports have never exceeded 6 percent of annual U.S. production. From an annual volume of 1 billion board feet in the late 1960's, export volume increased to 1.8 billion board feet in 1973. Foreign sales declined in 1974, reflecting the effects of a worldwide recession. Exports have yet to recover to the 1973 volume. Small volumes of clear lumber and specialty items are shipped worldwide. The primary markets for U.S. softwood lumber in terms of volume are Canada, Europe, and Japan.

The Pacific Northwest accounts for about 45 percent of the volume of U.S. softwood-lumber export and Alaska, 21 percent. In the Pacific Northwest, export volume in recent years has amounted to about 7 percent of production (Ruderman 1979).

Exports of softwood plywood from the United States were below 100 million square feet until 1969 (table 7). In the 1970's, volume increased to a record high of 791 million square feet in 1975. Volume declined from 1975 through 1978. Softwood-plywood exports have never exceeded 6 percent of annual U.S. production.

Most of the growth in export sales of softwood plywood in the mid-1970's resulted from expanded demand in Canada and Common Market countries. Annual shipments of softwood plywood to Japan have never exceeded 10 million square feet.

Table 6--Exports of softwood lumber from the United States, by destination, 1950-78 (Million board feet)

Year	Destination					
	Canada	Europe	Central and South America	Japan	Other	Total
1950	41.7	83.1	136.8	5.7	139.4	406.8
1951	71.4	324.2	164.6	18.7	296.8	875.7
1952	84.7	109.4	155.3	11.9	204.2	565.7
1953	75.8	71.2	136.8	58.0	170.8	512.6
1954	86.3	97.4	139.3	15.9	245.9	584.7
1955	119.1	95.8	147.6	29.5	260.4	652.4
1956	158.9	85.8	136.6	32.8	156.6	570.7
1957	138.6	88.1	148.4	47.4	200.4	623.4
1958	154.8	64.5	113.2	34.4	183.2	550.1
1959	198.5	80.5	104.2	52.6	172.2	607.9
1960	144.7	134.6	101.2	55.7	257.7	693.8
1961	150.2	108.4	80.3	146.8	132.5	618.6
1962	119.3	142.3	95.6	73.5	197.9	628.6
1963	107.9	198.9	92.0	112.5	231.7	743.1
1964	180.3	214.5	103.9	128.5	184.4	811.5
1965	184.0	229.3	104.8	103.1	157.7	778.9
1966	186.5	230.3	118.3	171.3	161.5	867.9
1967	207.6	241.0	112.5	260.7	143.5	965.2
1968	210.4	288.9	105.3	284.8	158.6	1,048.1
1969	198.3	264.6	102.5	309.6	148.9	1,023.8
1970	202.6	284.0	112.4	405.2	156.9	1,161.1
1971	206.3	213.8	87.6	287.4	141.1	936.2
1972	290.1	267.6	89.1	407.1	137.0	1,190.8
1973	388.4	494.2	101.6	564.5	204.1	1,752.8
1974	382.2	311.3	104.3	570.5	198.3	1,566.5
1975	397.5	218.7	109.1	515.3	164.9	1,405.4
1976	437.9	316.3	130.2	475.5	245.6	1,605.5
1977	377.0	288.6	136.8	436.7	198.2	1,437.3
1978	381.0	250.5	120.0	406.3	196.8	1,354.6

Source: Phelps (1977).

Table 7--Exports of softwood plywood from the United States, by destination, 1960-78
(Million square feet, 3/8-inch basis)

Year	Destination				
	Canada	Europe	Central and South America	Other	Total
1960	3.5	2.0	5.8	1.8	13.1
1961	3.1	2.4	5.4	2.8	13.7
1962	2.3	3.3	6.0	5.1	16.7
1963	1.0	6.2	7.4	2.9	17.5
1964	4.4	7.3	10.3	6.2	28.2
1965	1.7	10.8	10.6	7.2	30.3
1966	3.8	2.0	14.1	27.8	47.7
1967	2.8	49.3	18.0	14.8	84.9
1968	5.4	32.0	18.8	8.0	64.2
1969	47.6	126.2	17.5	8.0	199.3
1970	8.4	81.2	15.2	9.0	113.8
1971	13.9	61.0	14.9	9.2	99.0
1972	73.5	128.7	13.7	4.5	220.4
1973	106.1	269.9	65.2	21.2	462.4
1974	278.1	226.9	22.6	14.4	542.0
1975	394.2	363.3	17.5	15.9	790.9
1976	163.1	517.1	14.9	23.0	718.1
1977	42.7	210.9	13.8	19.6	287.0
1978	42.6	195.9	18.3	40.8	297.6

Source: Phelps (1977).

Producers in the Pacific Northwest have accounted for the bulk of the expansion of export sales. In the mid-1970's, these producers accounted for about 60 percent of total exports of softwood plywood. Foreign sales amount to less than 6 percent of softwood-plywood production in the Pacific Northwest.

Demands for softwood construction materials in Japan and Europe appear to have the most potential for affecting U.S. softwood-timber supplies and prices. The Canadian market for U.S. softwood lumber amounts to about 25 percent of total U.S. exports. It is based in part on the importation of products not readily available in Canada and also in part on the proximity of Canadian consumers to U.S. producers. Competition from Canadian producers and Canada's relatively small population limit the potential draw of this market for softwood lumber. Tariff and nontariff trade barriers on both sides of the border are likely to continue to affect U.S.-Canadian trade in softwood plywood.

Japan

Exports of softwood lumber from the United States to Japan amount to about 500 million board feet--1.8 percent of U.S. production and 35 percent of total exports. About 60 percent of U.S. exports to Japan originate in Alaska. Most of the remaining volume originates in the Pacific Northwest. In Japan, some U.S. lumber is used directly in the home-construction industry, but most of the volume--in the form of cants--is further processed.

In the Japanese market, U.S. softwood-lumber producers face competition primarily from Canadian softwood lumber, softwood logs and lumber from the Soviet Union, softwood logs from the United States, and softwoods from domestic producers in Japan (table 8). Hardwoods from Southeast Asia are also a form of indirect competition in that this lumber is used in home construction.

Almost all of the softwood-log volume imported into Japan is processed into lumber for use in the construction industry. In general, the Japanese construction industry is the driving force behind the markets for solid softwood products and accounts for about 75 percent of all lumber consumption.

Table 8--Timber products consumed in Japan, 1975-77, by source of supply (Million cubic feet, roundwood equivalent)

Item and source	1975	1976	1977
Domestic supply	1,583.5	1,642.5	1,610.2
Foreign supply:			
Logs:			
United States	368.0	397.1	373.9
U.S.S.R.	273.1	292.0	276.6
Canada	6.6	10.1	15.8
Asia	644.5	815.4	784.7
New Zealand	18.1	31.6	30.9
Other	2.3	1.9	5.4
Total	1,312.6	1,548.1	1,487.3
Lumber:			
United States	78.3	78.2	70.2
U.S.S.R.	7.4	8.0	8.4
Canada	71.4	104.6	119.5
Asia	23.3	37.5	43.5
New Zealand	6.0	7.8	13.3
Other	0.6	0.8	2.2
Total	187.0	236.9	257.1
Wood chips and pulpwood:			
United States	232.0	234.0	229.1
Australia	77.0	92.2	111.7
New Zealand	10.6	9.3	14.3
Asia	39.1	30.5	28.5
U.S.S.R.	11.4	36.5	52.1
Other	1.3	10.0	16.5
Total	371.4	412.5	452.2
Woodpulp:			
United States	65.7	64.2	69.7
Canada	70.8	75.6	68.7
New Zealand	24.7	27.0	37.7
Western Europe	2.1	1.7	6.6
Other	3.0	4.8	4.7
Total	166.3	173.3	187.4
Paper and board:			
United States	7.7	7.2	10.5
Canada	2.8	5.6	6.4
Western Europe	4.8	6.7	8.4
Asia	2.7	0.4	0.3
Other	0.1	0.1	0.1
Total	18.1	20.0	25.7
Total other products	94.0	91.3	92.4
Total foreign supply	2,149.4	2,482.1	2,502.1
Total supply	3,732.9	4,124.6	4,112.3

Source: Derived from data published by Japan Forestry Agency, "Timber demand and supply for 1977-78, "Japan Lumber Journal, 19(8), April 29, 2978; and Ministry of Finance, Japan Tariff Association, "Japan exports and imports by county," Tokyo, December 1975, 1976, and 1977.

nited States producers have about 43 perent of the Japanese market for imported oftwood lumber and about 53 percent of the arket for imported softwood logs. In total, mports of softwood lumber and logs from he United States amount to about 29 perent of Japan's consumption of softwood onstruction materials.

ecause of tradition and lower cost, hardood plywood will probably continue its ominance of the plywood market. The impact f Japanese demand for softwood plywood on .S. softwood prices and supplies will robably continue to be negligible, at east for the next decade.

vailable information indicates a coninuing demand for imported softwood contruction materials in Japan. For example, rojections of the Japan Ministry of Agriulture and Forestry (1973) indicate that otal demand for forest products might be 0 percent higher in 1991 than in 1970.

uch of the growth in Japanese imports of imber products over the coming decades is xpected to be in response to demands for iber-based items (Japan Ministry of Agriulture and Forestry 1973). Compared with he rapid growth of the 1960's and early 0's, future demands for solid softwood onstruction materials in Japan appear elatively stable. The rise in imports of oftwoods during this period was keyed to a ise in housing starts and to a reduction n domestic supply. Spurred by the post-orld War II recovery of the Japanese conomy, annual housing starts increased rom about 400,000 in the early 1960's to a ecord high of close to 2 million in 1973. n recent years, housing starts have been veraging about 1.5 million per year. lthough some uncertainties exist about apanese housing patterns in the future, he number of starts will probably continue round current levels, with some variation ecause of cyclic ups and downs of the arket over the coming decade. The interction of this demand and alternative upply sources will ultimately determine he Japanese demand for U.S. softwoods.

Harvest of timber in Japan declined from 51.8 million cubic meters in 1967 to a low of 34.2 million cubic meters in 1975. In recent years, domestic harvest has increased, but still accounts for only about 34 percent of Japan's requirements for timber products. One of the rationales for the reduction in harvest was to give timber inventories a chance to build up after the effects of World War II. Timber-management activities of the past two decades will begin paying off more toward the late 1980's, but even then Japan will probably rely on imports for more than half of its softwood needs.

Over the next decade or so, the potential for expansion of softwood shipments from the Soviet Union to Japan appear limited (North and Solecki 1977). When the "BAM" Railroad is completed in the late 1980's, the potential for expansion appears better, but other priorities might limit increases in solid softwood exports.

Softwood-lumber production in British Columbia has the potential for expansion based on intensification of use and management of accessible timber inventories or through development of untapped timber resources in the northern part of the Province (Reed and Associates, Ltd. 1977). In addition to some expansion potential geared to Japanese needs, B.C. producers, especially on the coast, could shift sales of lumber to Japan from the United States and other markets. Currently, the United States takes 60 percent of B.C. lumber production; Canada, 26 percent; Japan, 6 percent; United Kingdom, 5 percent; and other countries, the remaining 3 percent.

North American timber processors have been promoting the use of the "2 X 4 platform frame" construction (PFC) method in Japan as a means to develop a market for dimension lumber of the sizes and grades used in North America. To date, the promotion efforts have met with limited success. Even if the PFC method is adopted on a wider scale, Canada might capture most of any expansion of the Japanese market for imported softwood lumber. Alternatively, Japanese processors might continue to import logs and manufacture sizes needed for PFC housing. Either way, the impact of PFC housing on Japanese demand for U.S. softwood lumber would tend to be limited.

Construction techniques in Japan, consumer preferences, and the structure of the timber industries in Japan are key considerations in attempting to judge potential Japanese responses to a more restrictive U.S. log-export policy. If U.S. logs were not available to Japan, Japanese importers could not shift rapidly to the purchase of 2 X 4's and dimension lumber from North America. The construction industry in Japan is geared to the use of 4 X 4's and other traditional sizes.

Much of the structural wood in a Japanese house is exposed, and Japanese consumers have a traditional preference for light-colored, straight-grained, relatively knot-free wood--such as western hemlock. If U.S. logs were not available, attempts to substitute logs from the Soviet Union, the other major softwood log supplier, would meet with consumer resistance.

Over the past twenty years, the structure of the Japanese sawmill industry has shifted from relatively small mills near the domestic Japanese timber resource to larger mills near the port of entry for imported logs. A significant share of the capacity represented by the larger mills would not be available for processing domestic Japanese logs if U.S. logs were not available. Transportation patterns and other logistical problems would tend to preclude a matching of Japanese timber resources with processing capacity.

Construction techniques, consumer preferences, and the structure of the Japanese timber industries will tend to constrain Japanese responses to a shift in U.S. log-export policy. In the sensitivity analysis to follow, we have attempted to demonstrate potential impacts on the market resulting from alternative Japanese responses to a ban on U.S. log exports, but anticipating Japanese responses exactly is impossible.

Europe

European demands for construction materials grew in response to postwar recovery of the economies of the area. Consumption of softwood lumber grew from 59 million cubic meters in 1960 to a historic high of 77 million cubic meters in 1973. Plywood consumption increased from 8.7 million cubic meters to 30.8 million cubic meters over the same period. For the most part, the supply sources that fed the increased demand were the Soviet Union, Scandanavia, and increased production in Western Europe. After a slump in demand in 1974, consumption has picked up, but has yet to exceed the record reached in 1973.

In 1973, the record year for U.S. softwood lumber exports to Europe, volume amounted to 494 million board feet--about 1.6 percent of total U.S. softwood-lumber production. In Europe, U.S. shipments amount to 2 to 3 percent of the market for imported softwood lumber.

mports of plywood from the United States ere a minor factor in the European market or panel products until the 1970's. Volume eached a record high of 517 million square eet in 1976--about 3 percent of U.S. prouction. Primary competition for the Euroean market comes from Canada, Scandanavia, nd domestic producers in Western Europe. fter the surge in sales in the mid-1970's, he United States accounted for about 3 percent of the European market for mported panel products. Export volume from he United States to Europe dropped in 1977 nd 1978, reflecting in part strong U.S. arkets for softwood plywood.

orth American trade associations are prooting the use of the PFC technique in urope as in Japan. Current construction echniques favor use of nonwood construction aterials or use of lumber and plywood of izes and standards that differ from North merican products. Widespread adoption of he PFC technique would generate more nterest in importing lumber and plywood rom the United States, but U.S. producers ould still have to meet the competition rom other supply sources.

rowth in exports of softwood lumber and lywood from the United States to Europe as been based in part on limited success f promotion efforts. Plywood has been ccepted for use as concrete-form material nd for packaging. The PFC technique has lso met with some success in Denmark and candanavia.

he growth in exports of U.S. lumber and lywood to Europe during the mid-1970's was ased primarily on expanded shipments from he Pacific Northwest. During 1973-76, or example, the volume of southern pine pecies amounted to only 6 percent of verage annual exports of 1.6 billion board eet of softwood lumber.

European demands for lumber and plywood derive primarily from the construction industry. For example, in 1970, 68 percent of softwood-lumber consumption was attributable to construction and for plywood, 50 percent (United Nations Economic Commission for Europe 1976). The European drain on the U.S. timber resource in the future will depend not only on the course of European demands but also on the availability of supplies from alternative sources.

Projections of future European demands indicate a slowly expanding market for lumber and a more rapidly expanding market for panel products (table 9). Panel products include fiberboard and particleboard, both more widely accepted for use in construction in Europe than in North America.

Table 9--Projected consumption[1] of sawnwood and wood-based panels for Europe (Million cubic meters)

Year	Sawnwood	Wood-based panels
1969-71 average	93.2	23.1
Projections:		
1980	99.2-104.8	45.9-47.4
1990	103.2-119.3	79.3-84.1
2000	109.8-144.1	130.1-143.3

[1] Range in consumption estimates based on alternative assumptions about future economic growth.

Source: United Nations Economic Commission for Europe (1976).

Expansion of supplies within Europe has some potential, but the expectation is for an expanding deficit in softwood lumber and plywood, which would have to be filled by imports. Questions have been raised about the ability of Scandanavia (United Nations Economic Commission for Europe 1976) and the Soviet Union (North and Solecki 1977) to expand production during the coming decade, suggesting the potential for expanded purchases from North America. Alternatively, European consumers could turn more to fiber-based construction materials and hardwoods as substitutes for softwood lumber and plywood. In addition, Canada might capture the major share of any expansion of shipments from North America to Europe.

Supply

Domestic Sources

Production of softwood plywood in the United States grew rapidly over the 1960's and 1970's (fig. 4). Producers in the South captured most of the growth in the market. Production in the West remained relatively stable, with some responses to changing market conditions. By the mid-1970's, the South accounted for about one-third of U.S. production.

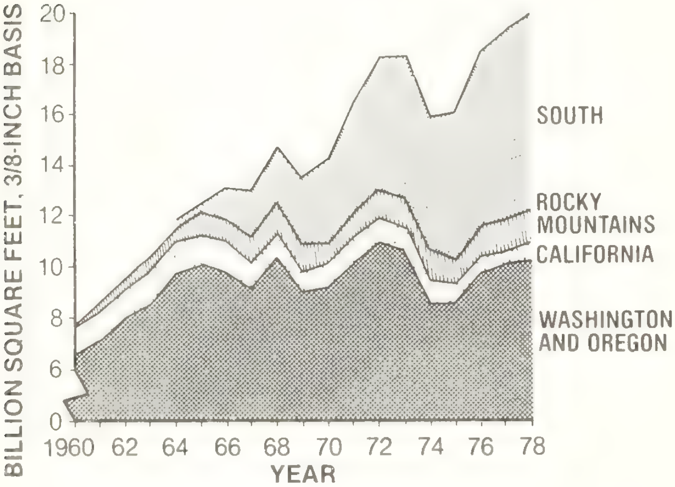


Figure 4.--Softwood-plywood production in the United States, by region 1960-78. Source: Ruderman (1978).

Production of softwood lumber in the United States amounted to about 31 billion board feet in 1976--the same amount as was produced in 1950 (fig. 5). During this period, output declined to a low of 26.1 billion board feet in 1961 and reached a record high of 31.6 billion board feet in 1973.

Output in each region has generally followed a pattern of declining during the late 1950's and increasing in the late 1960's and early 70's. By the mid-1970's, the West accounted for 70.2 percent of U.S. production, the South, 25.9 percent, and the North, 3.9 percent.

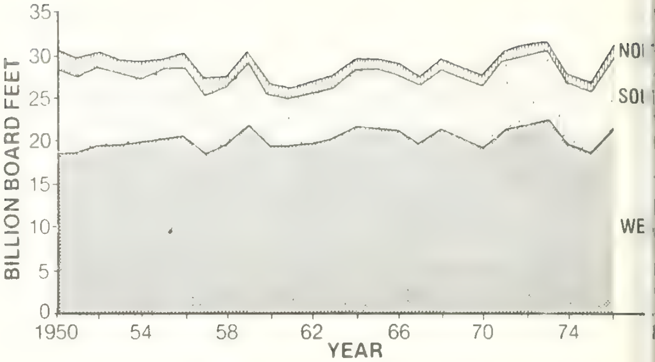


Figure 5.--Softwood-lumber production in the United States, by region, 1950-78. Source: Phelps (1977).

Supplies of softwood lumber and plywood a influenced by the availability of timber supplies, by the costs of labor and materials needed in the manufacturing process by the motivations of producers, and by t prices of these products. Demands and supplies of softwood end products interact with demands and supplies of standing tim to determine ultimate timber prices and timber-harvest levels. Demand for standin timber varies within the United States, depending on the types and sizes of timbe resources available, the types of end products being manufactured, and the degr of competition among timber processors fo raw materials.

egional differences in product mix are but ne indicator of the variation in types of emands affecting the timber resource. In he Western United States, mills are enerally geared to the processing of soft- ood lumber and plywood from old-growth imber. Currently, about 70 percent of the oftwood-timber harvest on the Pacific oast is used for lumber manufacture and 7 percent for plywood. Most wood fiber sed in pulp manufacture comes from mill esidue. In the Southern United States, bout 37 percent of the softwood timber arvest is used for lumber manufacture, and percent for plywood. About 52 percent of he roundwood harvest in the South is used or pulp manufacture. In addition, the pulp ndustry relies on mill residue for about 4 percent of its wood-fiber needs.

he ownership pattern of timber supply also aries among regions in the United States. or example, National Forest lands in the est account for about 39 percent of the otal softwood-timber harvest but, in the outh, National Forest lands account for nly about 3 percent.

vailable information indicates some otential for expansion of softwood-lywood production in the United States ver the coming decades (table 10). Some otential for expanding softwood-lumber roduction also exists.

Foreign Sources

The United States is self-sufficient in softwood logs and plywood. Since World War II, however, Canada has supplied an increasing share of U.S. needs for softwood lumber. By the mid-1970's, about 20 percent of U.S. softwood-lumber consumption was of Canadian imports (Phelps 1977). Much of the increase in volume during the 1960's was based on development of the timber resources in British Columbia.

Shipments of softwood lumber to the United States amount to about 80 percent of Canada's total exports of this commodity and about 60 percent of production.

Canada has potential for considerable expansion of softwood-lumber production (Reed and Associates, Ltd. 1977), based in part on development of currently untapped resources and in part on the possibility of management and use to increase timber supplies. One estimate (Aird and Ottens 1979) suggested that softwood lumber output in 2000 might be 22 billion board feet--double the production achieved in 1975.

able 10--Projected regional production of softwood lumber and plywood, and imports of oftwood lumber from Canada, 1990-2030

Year	Lumber production and imports (Billion board feet)					Plywood production (Billion square feet, 3/8-inch basis)			
	North	South	West	Total	Imports	North	South	West	Total
1990	1.3	10.7	19.5	31.5	12.7	0.1	10.5	12.2	22.8
2000	1.4	9.7	18.4	29.5	13.7	.1	11.2	11.6	22.9
2010	1.5	9.5	20.6	31.6	13.9	.1	12.2	11.5	23.8
2020	1.6	8.1	22.7	32.4	12.2	.1	12.9	10.5	23.5
2031	1.7	7.1	24.8	33.6	10.0	.1	13.1	9.5	22.7

ource: Adams and Haynes (1980).

Summary of Markets an Implications of Interactio

The Uncertain Alaska Situation

Over the decade of the 1980's,[1] ownership of significant volumes and acreages of timber will be transferred from the Federal government to Native Corporations in Alaska. The specific volume and the type of timber-flow policy to be exercised on these lands is uncertain. If the Native Corporations decide to enter the log-export market, annual volumes would probably exceed 100 million board feet and might reach several hundred million board feet, depending on timber-flow policies. Japan would probably be the destination for these logs. Logs from Alaska might be in competition with logs from the rest of the U.S. west coast, or the effect might be to reduce lumber exports from Alaska to Japan. We have not specifically considered Alaska export potential in our sensitivity analysis. The situation should be monitored, however, for developments that might affect market responses to U.S. log-export policy on the rest of the U.S. west coast.

In the United States, about 52 percent the softwood-timber harvest is used for manufacture of lumber, 12 percent for pl wood, 33 percent for pulp, and 5 percent for export (Phelps 1977). Demand for lum and plywood stems primarily from the domestic market--less than 6 percent of U.S. lumber production is exported and l than 5 percent of U.S. softwood-plywood output is exported.

The supply of softwood construction mate originates domestically for almost all plywood and 80 percent for lumber. Most the imported softwood lumber comes from Canada. Within the United States, lumber and plywood production in the West has tended to stabilize over the past 10 yea or so. Supply responses to increased domestic demand during this time have originated in Canada for softwood lumber in the Southern United States for softwo plywood.

Available information suggests little ch in the pattern of U.S. trade in solid softwood-timber products over the coming decade. The domestic market will remain driving force behind the softwood-lumber and softwood-plywood industries. Softwoo lumber imports from Canada will continue increase, but more interaction among U.S Canadian, and offshore markets may occur the future.

Any impacts of log exports on supplies a prices of domestic timber must originate primarily in the stumpage markets of the Pacific Northwest and work up through an interactive market system to affect end-product prices. If the impacts of log exports on domestic markets are to be assessed, the existence of interactions among supply regions suggests a need for means to simulate them. Simulation of market interactions provides the basis fo the sensitivity analyses to be discussed later.

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[1] For additional information on the timber market of southeast Alaska, see "An overview of some economic options for southeast Alaskan timber," by D. Darr, R. Glass, T. Ellis, and D. Schmiege. This is a cooperative report done by the Alaska Region, Juneau, Alaska; the Forest Products Laboratory, Madison, Wisconsin; and the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, and Juneau, Alaksa. Copies are available from the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

The Analytical Framework

arket responses and interactions from a hange in log-export policy would tend to ary, depending on the period considered. or example, in the short run of a year or o, market responses would tend to be contrained by inventories of logs and end roducts, availability of capacity, and vailability of transportation facilities. ver a longer period, these constraints end to become variables. In the sensitivity nalysis that follows, we have abstracted rom shortrun market responses. We have ssumed that a ban on softwood-log exports ould be in effect long enough so that any hortrun market dislocations would be esolved. This approach should not be interreted as minimizing possible shortrun mpacts of a change in log-export policy. he sizes and types of these impacts would ary, depending on market conditions. For xample, if U.S. processors were operating t capacity, less opportunity would be presnt for processing additional log volumes han if U.S. markets were less active. Some nalysts have suggested linking log-export olicy to shortrun market conditions (Wiener 973 Clawson 1975).

With the exception of Haynes (1976), who attempted to bracket the possible price impacts of banning log exports, each of the previous studies of the linkage between prices and exports has generally projected only one scenario for market responses to a change in trade policy. In general, these studies have concluded that Japan would purchase more lumber from Canada and the United States, but in total, a ban on U.S. log exports would not have much effect on U.S. end-product prices (Wiener 1973, Clawson 1975). The Stanford Research Institute concluded that stumpage prices in the Pacific Northwest would be lower after a ban on log exports.[2]

Previous analyses have attempted to account for the interaction of Japanese, U.S., and Canadian markets, but they have not explicitly considered interactions among U.S supply regions.

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[2] Unpublished report for the Pac. Northwest Reg. Comm., Vancouver, Wash., "Benefits and costs of alternative log export policies--phase one report, and alternative log export policies for the long term--phase two report," by the Stanford Res. Inst., 1974.

Sensitivity Analyses

The specifics of how our simulation model operates are discussed in detail in Adams and Haynes (1980) and described briefly in the appendix. No attempt was made to simulate interactions in the timber markets of Japan. In concept, the Japanese timber economy would respond to a ban on U.S. log exports through market interactions that would affect the use of all available construction materials, regardless of source. For example, additional log volumes might be purchased from Siberia, domestic harvest in Japan might increase, or the use of nonwood construction materials might increase. The response of Japanese producers and consumers in using other sources of building materials is uncertain and will likely remain one of the major unknowns in attempting to rationalize U.S. log-export policy.

Regardless of how much detail is used in assessing market interactions, any analysis of the linkage between log exports and supplies and prices of domestic timber must rest on a set of assumptions. Our simulation model is based for the most part on time-series data for 1950-76. As used in this study, the model solves for stumpage prices, timber harvest, and production, consumption, and prices of softwood lumber and plywood in U.S. regions and in Canada. Softwood-lumber imports from sources other than Canada and all softwood exports are specified and fed into the model to interact with U.S. and Canadian supplies and demands.

The simulation model treats a ban on log exports as a decrease in the demand for stumpage in log-exporting regions. Based on historical relationships within and among regions and based on assumptions about offshore shipments, the model determines how timber markets in each region would be affected.

Base Scenario

In the sensitivity analysis, we show the effects of a ban on log exports for each year from 1980 to 1990 under alternative sets of assumptions about Japanese responses. We have assumed that during each year 2.5 billion board feet of softwood logs, Scribner scale, would have been exported from Washington and Oregon without a change in U.S. log-export policy and, from northern California, 100 million board feet. The assumption of constant export volume is consistent with a view of relatively stable Japanese demand for construction materials over the coming decade.

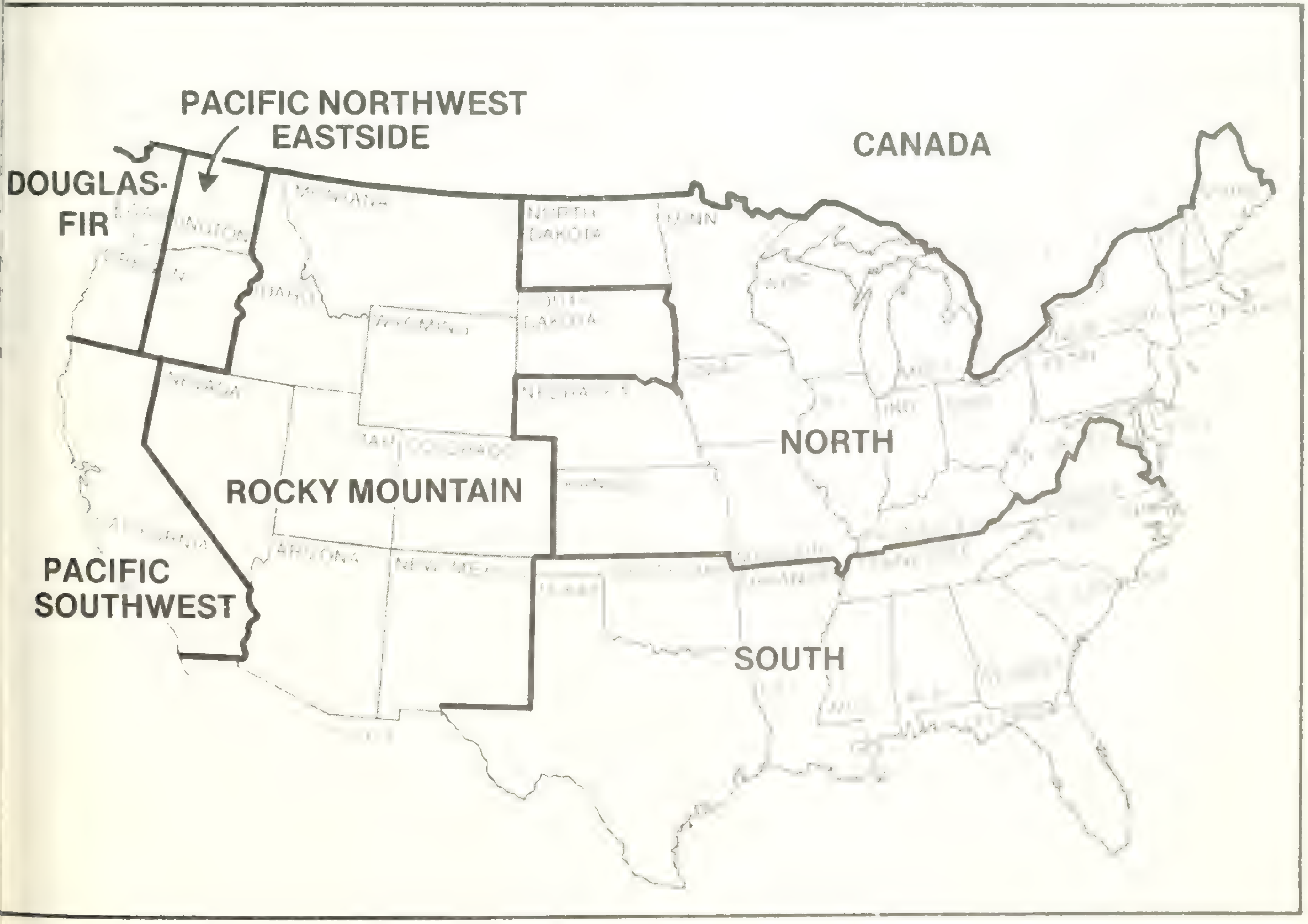
The projected volumes of log exports also have an implicit assumption that the west coast States could produce and sell 2.6 billion board feet to the log-export market each year during the projection period. Available information indicates that over the next two decades, timber harvest on industry lands on the west coast will decline (Gedney et al. 1975, Beuter et al. 1976, and Oswald 1978). In addition, more of the timber from private and public lands will be second growth. These changes in the volume and character of log supplies on the west coast may tend to dampen export volumes below 2.6 billion board feet during the latter part of the projection period.

sing our simulation model, our estimates f log- and lumber-export volumes, and stimates of domestic and other foreign emands and supplies of timber products onsistent with the Timber Assessment (USDA orest Service 1979), we projected timber arvest, stumpage prices, and production nd prices of softwood lumber and plywood or each U.S. region shown in figure 6. In ddition, the model solves for the volume f softwood-lumber production in Canada and or exports of softwood lumber from Canada o the United States. This projection contituted our base scenario for use in dentifying the effects of a ban on log xports under each set of assumptions about apanese responses to the change in U.S. rade policy.

Alternative Scenarios

As used in the following discussions, a "scenario" describes market responses to a ban on U.S. log exports under a set of assumptions. Scenarios differ according to the underlying assumptions about Japanese responses to a ban and according to assumptions about the response of processing capacity in the Douglas-fir region.

Figure 6.--Product and stumpage supply regions.



For each scenario, we have assumed that Japanese timber processors would recover 4.42 billion board feet of softwood lumber from the 2.6 billion board feet of logs that would have been purchased from the United States during each year of the projection period without a change in U.S. trade policy. We have also assumed that U.S. producers would recover only 3.38 billion board feet of softwood lumber from 2.6 billion board feet of logs. Recovery or overrun factors of 1.7 for Japan and 1.3 for the west coast are consistent with current industry averages. The higher recovery in Japan is attributable in part to thinner saws, very little planing or other surface preparation, and sawing of generally larger lumber dimensions. For each scenario, Japanese consumers are assumed to have to replace the equivalent of 4.42 billion board feet of softwood lumber during each year of the projection period.

Under each scenario, a ban on log exports is assumed to decrease annual stumpage demands by 2.5 billion board feet in the Douglas-fir region and by 100 million board feet in the Pacific Southwest region.

The sensitivity analyses were done only for the decade of the 1980's. The 10-year projection, however, adequately demonstrates the types of impacts that a ban on log exports might have on timber supplies and prices in the United States under each of the assumed scenarios.

Scenario 1

What would be the effect of a ban on lo
exports on U.S. markets if Japan purcha
the lumber equivalent of log-export vol
from the United States? This scenario
favors U.S. lumber processors. It assum
that Japan would purchase an additional
4.42 billion board feet of softwood lum
from the United States. Although favori
U.S. processors, the scenario has the
potential to be detrimental to U.S. consumers if significant volumes of lumber
would be diverted from the U.S. to the
Japanese market, or if Canadian imports
would not be able to respond to possibl
higher prices in the United States. The
scenario also favors U.S. stumpage owne
especially in the log-exporting regions
that expanded demand for lumber might ha
the effect of offsetting any reductions
stumpage prices caused by removal of lo
export demands from the timber markets.
purpose of the scenario is to get some i
of the effects on U.S. timber markets o
replacing Japanese log demand with Japa
lumber demand. No additional direct Japa
drain on the Canadian softwood resource
assumed. Any increase in exports from Ca
to the United States in response to high
prices attributable to U.S. softwood-lum
exports to Japan, however, would reflect
indirect Japanese drain on the Canadian
resource.

In the model, 96 percent of the expanded
U.S. export of 4.42 billion board feet o
softwood lumber is allocated to the
Douglas-fir region and 4 percent is
allocated to the Pacific Southwest regio
The west coast is judged to be in the be
position to respond to increased Japanes
demands for softwood lumber. No assumpti
is made about the response of processing
capacity: Timber harvest and processing
each region are solved by the model.

cenario 2

hat would be the effect of a ban on log xports on U.S. markets if Japan did not uy any additional softwood lumber from orth America? The purpose of this scenario s to get some idea of the maximum stumpage nd reduction of end-product prices that ight be associated with a ban on softwood-og exports. Japan is assumed to find a eplacement for the equivalent of 4.42 bilion board feet of softwood lumber by using onwood substitutes, expanding hardwood onsumption, increasing domestic harvest, nd increasing purchases of softwoods from iberia. The demand for softwood lumber rom North America is assumed to be unafected. Removal of log-export demand in the xporting regions would have the effect of owering stumpage prices in these regions. hese lower stumpage prices would then nteract with other components of the imber economy to affect prices and production in the United States and U.S. mports from Canada.

he scenario would be favorable to U.S. onsumers in that end-product prices would e lowered, favorable to U.S. processors in hat stumpage prices would be lowered, and etrimental to stumpage owners.

Scenario 3

What would be the effect of a ban on log exports on U.S. markets if Japan bought Canadian lumber as a replacement for U.S. logs?

Under the terms of this scenario, Japan is assumed to purchase an additional 4.42 billion board feet of softwood lumber from Canada. Whether or not the scenario should be considered favorable or unfavorable to any one segment of the U.S. timber economy (consumers, processors, and stumpage owners) depends on how markets interact. Softwood-lumber exports from the United States are assumed to be unchanged.

Scenario 4

What would be the effect of a ban on log exports on U.S. markets if Japan purchased the lumber equivalent of log-export volume from the United States, but lumber-processing capacity did not expand in the Douglas-fir region? Proponents of log-export restriction assume that processing capacity would expand to use any additional log volumes made available through a ban. But what if capacity did not respond and, at the same time, Japan stepped up purchases of softwood lumber from the United States? The purpose of the scenario is to determine the effects of this type of market situation on prices and production in the United States and on softwood-lumber imports from Canada.

As in scenario 1, 96 percent of the increased lumber exports from the United States is assumed to originate in the Douglas-fir region and 4 percent in the Pacific Southwest region. Additional lumber-export volumes are assumed to total 4.42 billion board feet.

Scenario 5

What would be the effect of a ban on log exports on U.S. markets if Japan responded by purchasing lumber from both Canada and the United States?

Under the terms of this scenario, Japan is assumed to replace the lumber equivalent of U.S. softwood-log export volume by purchasing an additional 2.21 billion board feet of softwood lumber from Canada and an additional 2.21 billion board feet of softwood lumber from the United States.

As in scenario 1, 96 percent of the increased lumber exports from the United States is assumed to originate in the Douglas-fir region and 4 percent in the Pacific Southwest region.

Simulation Results

We did the sensitivity analysis in an attempt to come up with general stateme about the effects of a ban on log expor on prices, production, and trade in the U.S. softwood-lumber and softwood-plywo industries. Detailed results of the simulations are shown in this section o the report for each scenario.

The results of our sensitivity analysis should be viewed as general indications f how markets would respond to a change i U.S. log-export policy rather than predictions of these responses. In additio the results of our analysis should be interpreted as indicating future market responses based on historical patterns interactions among markets. We have litt e in the way of historical precedent to j ge precisely how producers and consumers w ld respond to a ban on U.S. softwood-log exports.

National Impacts of Alternatives

Production, consumption, and imports of softwood lumber

Under the terms of scenarios 1 and 3, U. consumption of softwood lumber would dec n in the early 1980's and increase in the latter part of the decade, reflecting ar increase in domestic production (table 1

Under the terms of scenario 2, Japan is assumed to purchase no additional softwc construction materials from North Americ after a ban on U.S. log exports. The resulting decrease in stumpage demands o the west coast would have the effect of stimulating lumber production with the domestic market as the intended outlet.

able 11--Base-level projection and projected changes in softwood-lumber production, imports, exports, and onsumption, by scenario, 1980-90 (Million board feet)

	Base				Scenario 1				
ear	Production	Exports	Imports	Consumption	Production	Exports	U.S. Consumption of U.S. Production	Imports	Consumption
980	31,659	1,369	7,806	38,086	+2,256	+4,420	-2,164	+1,228	-936
981	31,901	1,392	8,246	38,755	+2,494	+4,420	-1,926	+1,431	-495
982	32,062	1,415	8,683	39,330	+2,795	+4,420	-1,625	+1,382	-243
983	31,987	1,438	9,137	39,686	+3,011	+4,420	-1,409	+1,315	-94
984	32,079	1,461	9,591	40,209	+2,984	+4,420	-1,436	+1,269	-167
985	32,029	1,485	10,033	40,577	+3,101	+4,420	-1,319	+1,238	-81
986	31,977	1,508	10,498	40,967	+3,131	+4,420	-1,289	+1,203	-86
987	31,860	1,531	11,043	41,372	+3,240	+4,420	-1,180	+1,110	-70
988	31,709	1,554	11,627	41,782	+3,555	+4,420	-865	+869	+4
989	31,476	1,577	12,206	42,105	+3,964	+4,420	-456	+632	+176
990	31,416	1,600	12,740	42,556	+3,947	+4,420	-473	+521	+48

	Scenario 2					Scenario 3				
ear	Production	Exports	U.S. Consumption of U.S. Production	Imports	Consumption	Production	Exports	U.S. Consumption of U.S. Production	Imports	Consumption
980	+863	0	+863	-494	+369	+1,899	0	+1,899	-2,635	-736
981	+1,142	0	+1,142	-775	+367	+2,251	0	+2,251	-2,574	-323
982	+1,326	0	+1,326	-972	+354	+2,540	0	+2,540	-2,716	-176
983	+1,547	0	+1,547	-1,168	+379	+2,699	0	+2,699	-2,789	-90
984	+1,702	0	+1,702	-1,353	+349	+2,729	0	+2,729	-2,876	-147
1985	+1,977	0	+1,977	-1,595	+382	+2,851	0	+2,851	-2,933	-82
1986	+2,370	0	+2,370	-1,918	+452	+2,883	0	+2,883	-2,996	-113
1987	+2,663	0	+2,663	-2,362	+301	+2,966	0	+2,966	-3,129	-163
1988	+3,184	0	+3,184	-2,866	+318	+3,167	0	+3,167	-3,241	-74
1989	+3,766	0	+3,766	-3,371	+395	+3,414	0	+3,414	-3,429	-15
1990	+3,998	0	+3,998	-3,836	+162	+3,617	0	+3,617	-3,567	+50

	Scenario 4					Scenario 5				
1980	+1,073	+4,420	-3,347	+1,867	-1,480	+2,154	+2,210	-56	+1,333	+1,277
1981	+1,004	+4,420	-3,416	+2,356	-1,060	+2,426	+2,210	+216	+1,088	+1,304
1982	+1,073	+4,420	-3,347	+2,572	-775	+2,683	+2,210	+473	+725	+1,198
1983	+1,087	+4,420	-3,333	+2691	-642	+2,894	+2,210	+684	+356	+1,040
1984	+946	+4,420	-3,474	+2,754	-720	+2,944	+2,210	+734	-63	+671
1985	+924	+4,420	-3,496	+2,885	-611	+3,139	+2,210	+929	-487	+442
1986	+981	+4,420	-3,439	+2,953	-486	+3,152	+2,210	+942	-933	+9
1987	+1,007	+4,420	-3,413	+2,899	-514	+3,186	+2,210	+976	-1,463	-487
1988	+1,137	+4,420	-3,283	+2,809	-474	+3,424	+2,210	+1,214	-2,075	-861
1989	+1,258	+4,420	-3,162	+2,759	-403	+3,632	+2,210	+1,422	-2,695	-1,273
1990	+1,169	+4,420	-3,251	+2,755	-496	+3,599	+2,210	+1,389	-3,263	-1,874

Consumption would decrease under scenario 4, which assumes that U.S. lumber exports would increase by 4.42 billion board feet and that no new processing capacity would be constructed in the Douglas-fir region.

Under scenario 5, consumption would increase initially and then decline in response to a decline in imports from Canada.

Production of softwood lumber in the United States would increase under the terms of each scenario. The increase in production would be least under scenario 4 and generally highest under scenario 1.

Consumption of domestically produced lumber in the United States would increase under scenarios 2, 3, and 5. The increase would be highest for scenario 3, which assumes that Canadian sales of softwood lumber to Japan would expand by 4.42 billion board feet.

Imports of softwood lumber from Canada would tend to offset any effect of U.S. log-export policy on U.S. consumption of softwood lumber. In scenarios 1 and 4, imports would increase in response to higher prices generated by expanded U.S. exports of softwood lumber. Under scenarios 3 and imports would generally decline--produc of softwood lumber in Canada would expa by less than the assumed increase in Canadian exports to Japan. Under scenar imports would decline in response to lo prices generated by expanded U.S. produ of softwood lumber destined for the domestic market.

Production and consumption of softwood plywood

We have assumed that U.S. imports and exports of softwood plywood would be unaffected by changes in U.S. softwood l export policy. Thus, changes in producti would equal changes in consumption. Production of softwood plywood would increa under the terms of each scenario (table The increase would be largest under scenario 4. Softwood-plywood productio would increase by less than 5 percent fc any one year and in any scenario.

Table 12--Base-level projection of production and projected changes in softwood-plywood consumption, by scenario, 1980-90 (Million square feet, 3/8-inch basis)

Year	Base	Scenario				
		1	2	3	4	5
1980	20,158	+253	+406	+296	+420	+286
1981	20,467	+270	+422	+304	+450	+282
1982	20,690	+299	+483	+359	+490	+309
1983	20,942	+297	+486	+332	+545	+334
1984	21,220	+294	+455	+336	+511	+296
1985	21,479	+259	+563	+572	+748	+560
1986	21,726	+330	+481	+328	+557	+329
1987	21,993	+334	+452	+340	+654	+343
1988	22,211	+336	+459	+373	+815	+363
1989	22,451	+307	+417	+374	+902	+357
1990	22,693	+286	+423	+327	+1,006	+348

ices for softwood lumber

ftwood-lumber prices in the United States
ald decrease under the terms of scenario 2
d increase under the terms of scenario 4
able 13). Under scenario 2, the ban on
ftwood-log exports would have the effect
increasing supplies for the domestic
rket, and we have assumed the absence of
creased Japanese demand for softwood con-
ruction materials. Increased supplies and
creased Japanese demands would result in
creased prices. Under scenario 4, we have
sumed that Japan would purchase the lumber
uivalent of log-export volume, resulting
a net increase in demand for softwood
nstruction materials. We have also assumed
at no new lumber-processing capacity
uld be constructed in the Douglas-fir
gion, thereby diverting production from
e domestic to the export market. Increased
reign demand and reduced domestic supplies
uld result in higher prices.

le 13--Base-level projection and projected changes in wholesale
ce index[1] for softwood lumber, by scenario, 1980-90

ear	Base	Scenario				
		1	2	3	4	5
980	155.3	+9.9	-4.0	+6.2	+15.9	+9.2
981	158.0	+4.6	-6.2	+3.2	+10.6	+4.3
982	162.4	+.9	-6.2	-.7	+8.1	+.2
1983	166.2	+.6	-4.5	-.4	+6.8	+.9
1984	170.2	+1.1	-5.3	-.7	+5.6	+.6
1985	174.3	0	-3.1	-.9	+5.9	+1.2
1986	179.5	-.2	-5.0	-.9	+4.8	-.3
1987	183.8	-.2	-3.0	-.6	+4.7	+.2
1988	188.3	+1.3	-3.1	-1.1	+4.9	[illegible]
1989	192.8	-.9	-2.6	+.1	+3.8	-.2
1990	199.8	-1.5	-4.0	-3.7	+1.0	-2.5

1967 = 100.

The patterns of price changes for the other scenarios are mixed, increasing in some years and decreasing in others. In general, the price changes for scenarios 1, 3, and 5 would amount to less than 2 percent in any year. The mixed pattern of price increases and decreases and the relatively small sizes of price changes suggest that softwood-lumber prices would probably change little under scenarios 1, 3, and 5.

Prices for softwood plywood

Softwood-plywood prices would decline under the terms of each scenario (table 14). The decline would be largest under scenario 4, reaching about 7 percent by 1990. Plywood prices would decline by less than 5 percent for the other scenarios. The decline in prices is attributable to increased plywood production brought about by lower stumpage prices. The effect of the ban on log exports on stumpage prices is discussed later.

[illegible]
index[1] for softwood plywood, by scenario, 1980-90

Year	Base	Scenario				
		1	2	3	4	5
1980	158.3	-3.4	-5.9	-4.2	-5.2	-3.6
1981	162.7	-4.0	-6.5	-3.9	-6.4	-3.7
1982	166.4	-3.4	-6.2	-3.5	-6.2	-3.4
1983	169.7	-3.6	-6.3	-4.4	-6.1	-3.5
1984	173.5	[illegible]	-6.8	[illegible]	-6.5	-4.8
1985	177.3	-4.7	-6.8	-5.1	-7.3	[illegible]
1986	180.6	-4.7	-6.9	-5.1	-8.0	-4.9
1987	183.9	-4.6	-6.5	-4.7	-9.0	-5.1
1988	187.2	-5.0	-6.0	-4.6	[illegible]	[illegible]
1989	190.5	-4.4	-5.7	[illegible]	[illegible]	-4.5
1990	193.7	[illegible]	-5.5	-4.6	[illegible]	[illegible]

[illegible] 100.

The balance of trade

According to the patterns of U.S. lumber exports, imports, and log exports implied by each scenario, the U.S. balance of trade would generally be negatively affected by a ban on log exports (table 15). The exceptions are scenarios 1 and 5 towards the end of the 1980's. For these two scenarios, the positive effect of a ban on the balance of trade reflects a decline in imports from Canada.

Table 15--Change in balance of trade, by scenario, 1980-90
(Millions of dollars)

Year	Scenario				
	1	2	3	4	5
1980	-31	-397	-109	-95	-329
1981	-74	-374	-144	-171	-307
1982	-75	-365	-144	-225	-280
1983	-76	-355	-140	-244	-240
1984	-74	-341	-133	-264	-191
1985	-70	-320	-128	-288	-143
1986	-74	-291	-127	-309	-84
1987	-59	-240	-111	-308	-9
1988	-14	-182	-99	-310	+75
1989	+6	-120	-81	-317	+163
1990	+19	-70	-75	-340	+246

Regional Impacts of Alternatives

Stumpage prices

Changes in log-export policy and lumber exports on the west coast would set in motion interactions among softwood marke in the United States and Canada. These interactions would ultimately affect stumpage prices in other U.S. supply regions. Under each scenario, the effect stumpage prices would be greatest in the Douglas-fir region, where they would dec under each scenario (table 16). Stumpage prices in the Pacific Southwest region would be affected under each scenario, bu less than in the Douglas-fir region. Stumpage prices in other regions would generally be affected most under scenari 4, followed by scenario 2. Under scenari 4, stumpage prices in regions not export logs would increase in response to highe lumber prices generated by increased expo and by a lack of additional capacity in t Douglas-fir region. Under scenario 2, stumpage prices in regions not exporting logs would generally decrease. Lumber an plywood production would increase in the log-exporting regions, decreasing end-product prices and eventually decreasing stumpage prices in other regions.

Stumpage prices in regions not exporting logs under scenarios 1, 3, and 5 would be generally affected, but the pattern would be mixed and the changes relatively small. For example, the change in price in the South would generally be less than one dollar in any one year.

ble 16--Base-level projection and projected changes in regional softwood stumpage prices, by scenario and gion, 1980-90 (Dollars per thousand board feet, log scale)

	Base						Scenario 1				
ar	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	North	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South
80	76.20	31.45	39.30	28.23	55.83	27.61	-37.47	+7.18	-1.41	+8.22	+1.46
81	77.86	38.66	44.48	38.13	59.08	28.20	-32.15	+3.08	-2.96	+5.59	+1.16
82	80.91	44.88	46.31	35.37	62.68	28.74	-31.33	+1.43	+0.05	+2.72	+0.46
83	83.53	43.28	47.17	37.68	66.00	29.00	-33.36	-1.57	+0.75	-0.67	+0.36
84	86.39	45.27	51.84	38.54	69.20	29.39	-36.78	+0.02	-4.76	+1.81	+0.04
85	88.45	48.32	54.63	41.81	72.20	29.70	-36.61	+0.08	-3.29	-0.53	-0.14
86	91.08	50.86	56.95	44.79	75.16	29.87	-38.20	-1.42	-2.14	-1.94	-0.49
87	93.86	52.99	60.49	45.98	77.83	30.08	-37.77	-1.51	-3.07	-1.18	-0.71
88	97.11	54.38	63.40	48.27	80.33	30.25	-36.57	-1.58	-1.86	-0.75	-0.41
89	99.86	57.07	65.99	50.65	82.83	30.50	-35.16	-2.84	-0.21	-1.76	+0.08
90	104.47	58.82	70.84	52.63	85.33	30.62	-36.64	-2.64	-3.19	-0.73	+0.18

	Scenario 2					Scenario 3				
ar	Douglas-fir	Pacific Northwest East side	Pacific South-west	Rocky Mountain	South	Douglas-fir	Pacific Northwest East side	Pacific South-west	Rocky Mountain	South
80	-45.51	-1.31	-7.04	-2.79	-1.10	-39.73	+4.28	-4.73	+9.09	+1.17
81	-42.12	-4.57	-7.73	-5.99	-1.56	-34.17	+1.80	-4.03	+5.44	+0.72
82	-44.09	-7.65	-6.39	-3.99	-1.57	-33.81	-0.14	-0.65	+3.63	+0.04
83	-45.02	-5.78	-3.51	-4.77	-2.86	-35.78	-2.85	-1.50	+2.29	-0.65
84	-45.90	-5.78	-3.58	-3.64	-3.15	-39.13	-3.33	-3.72	+2.77	-1.34
85	-45.13	-5.97	-3.54	-5.61	-3.09	-38.99	-2.82	-2.42	+0.74	-1.22
86	-43.79	-5.98	-1.96	-9.30	-2.91	-40.32	-3.35	-2.37	+0.44	-1.26
87	-43.89	-3.56	-3.58	-10.61	-3.04	-41.61	-2.66	-2.71	+1.37	-1.67
88	-42.05	-1.66	-2.36	-11.68	-5.02	-40.84	-1.46	-3.34	+1.82	-3.69
89	-39.03	-1.46	-2.47	-12.30	-1.58	-40.10	-0.58	-4.62	+0.85	-0.49
90	-41.51	+0.49	-3.40	-14.17	-1.57	-40.94	-0.40	-5.94	-0.46	-0.34

	Scenario 4					Scenario 5				
80	-57.43	+9.87	-1.35	+12.77	+2.75	-38.39	+6.22	-1.72	+9.61	+1.40
81	-57.76	+5.67	-2.73	+10.26	+2.02	-32.87	+3.79	-3.29	+6.24	+0.80
82	-59.97	+6.01	+1.65	+10.47	+1.89	-32.58	+1.66	-0.66	+4.79	+0.22
83	-63.87	+3.27	+6.55	+7.75	+1.05	-33.95	-0.54	-1.27	+1.69	+0.13
84	-64.39	+0.96	+3.84	+8.76	+1.03	-37.40	-0.14	-3.80	+1.64	-0.14
85	-67.20	+2.15	+0.31	+6.80	+1.53	-37.09	+1.86	-2.17	-0.06	+0.02
86	-67.73	+1.74	+0.43	+3.94	+1.67	-38.99	-0.88	-2.48	-0.34	-0.18
87	-69.57	+1.27	+0.08	+4.62	+1.47	-40.26	-1.63	-2.91	0	-0.36
88	-71.50	+1.72	-0.33	+4.10	-0.24	-39.28	+1.07	-2.60	+0.11	-2.74
89	-74.11	+0.87	-0.32	+4.21	+2.63	-38.61	+1.78	-3.20	-1.00	+0.16
90	-76.91	+0.75	-5.36	+4.22	+2.52	-42.08	+1.25	-5.07	-0.75	-0.03

The size of the stumpage price decreases in the Douglas-fir region under scenario 4--over 50 percent of base-level projections--suggest that at least some new capacity would be constructed. The low stumpage prices would be an inducement for establishment of new capacity. Exactly how much new capacity might be constructed remains uncertain, however; stumpage prices are only one factor considered in the decision to build processing capacity.

Stumpage prices and other aspects of timber markets in the northern region are assumed to be unaffected by changes in log-export policy for the west coast.

Timber harvest

Total U.S. timber harvest would decline after a ban on log exports (table 17). For scenarios 1, 3 and 5, the decline would generally amount to 1 to 1.5 billion board feet per year. Most of the harvest decline under these three scenarios would be concentrated in the Douglas-fir region. Harvest in any one of the other regions would generally change by less than 50 million board feet.

Under scenario 2, harvest would decline by about 10 percent in the Douglas-fir region in response to lower stumpage prices. Harvest would generally decline by several hundred million board feet per year in the South. Harvest changes in other regions would generally amount to less than 50 million board feet per year.

Under scenario 4, annual harvest in the Douglas-fir region would generally decline by over 2 billion board feet. Timber harvest in the South would generally increase by over 100 million board feet per year. In other regions, the change in harvest would be relatively small.

Softwood-lumber production

Under scenarios 1, 4 and 5, the general increase in softwood lumber production i regions not exporting logs is attributabl in part to higher lumber prices generate through increased lumber exports (table 1 For scenarios 1 and 5, the net increase i U.S. production is concentrated in the Douglas-fir region. Lumber production is assumed to be unchanged in this region under the terms of scenario 4.

Under scenario 2, softwood-lumber product in the Douglas-fir region would increase over 2 billion board feet per year durin the mid and late 1980's. This increase would be offset somewhat by a decline in production in the South. Output in the Douglas-fir region would also expand by over 2 billion board feet per year under the terms of scenario 3. With the excepti of a decline in production in the South during the late 1980's, output would generally increase in other U.S. regions.

Softwood-plywood production

Lower stumpage prices in the Douglas-fir region generated by a ban on log exports would lead to significant expansions of softwood-plywood production for all scenarios (table 19). The increase competitiveness of producers there would generally lead to reduced output in other regions.

Production in the Douglas-fir region woul expand least under scenario 1 and most under scenario 4, corresponding with the decline in stumpage prices there. The decline would be largest under scenario 4 and smallest under scenario 1.

T le 17--Base-level projection and projected changes in regional softwood timber harvest, by scenario and region, 1980-90
(llion board feet)

	Base							Scenario 1					
Y r	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	North	Total	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	Net change in harvest
1 0	13,636	2,958	4,743	4,629	22,585	3,656	52,207	-1,487	+51	-31	+47	+168	-1,252
1 1	13,570	3,010	4,808	4,729	23,143	3,727	52,987	-1,302	+19	-63	+31	+95	-1,220
1 2	13,560	3,053	4,797	4,754	23,734	3,798	53,696	-1,201	+6	+4	+14	+33	-1,144
1 3	13,530	3,037	4,765	4,760	24,287	3,858	54,237	-1,213	-15	+19	-6	+20	-1,195
1 4	13,507	3,049	4,814	4,788	24,811	3,923	54,892	-1,273	-3	-97	-22	-15	-1,410
1 5	13,454	3,069	4,821	4,831	25,297	3,986	55,458	-1,247	-3	-61	-37	-38	-1,386
1 6	13,422	3,085	4,817	4,872	25,762	4,043	56,001	-1,232	-13	-34	-45	-78	-1,402
1 7	13,394	3,098	4,838	4,903	26,178	4,104	56,515	-1,139	-14	-51	-41	-102	-1,347
1 8	13,380	3,106	4,844	4,941	26,566	4,161	56,998	-1,017	-14	-23	-39	-65	-1,158
1 9	13,347	3,124	4,844	4,979	26,940	4,222	57,456	-892	-18	+10	-45	-9	-954
1 0	13,374	3,134	4,886	5,016	27,305	4,275	57,990	-870	-21	-47	-40	-258	-1,236

	Scenario 2						Scenario 3					
Y r	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	Net change in harvest	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	Net change in harvest
1 0	-1,802	-9	-151	-16	-127	-2,150	-1,575	+31	-102	+52	+104	-1,490
1 1	-1,677	-33	-158	-34	-140	-2,042	-1,375	+11	-81	+30	+57	-1,350
1 2	-1,666	-55	-121	-22	-179	-2,043	-1,288	-4	-4	+19	-5	-1,282
1 3	-1,610	-39	-53	+23	-321	-2,000	-1,293	-22	+22	=11	-70	-1,397
1 4	-1,549	-37	-51	+49	-349	-1,937	-1,345	-26	-66	+14	-127	-1,550
1 5	-1,426	-38	-47	+55	-331	-1,787	-1,316	-21	-36	+1	-115	-1,487
1 6	-1,283	-37	-10	+53	-299	-1,576	-1,287	-24	-32	0	-155	-1,498
1 7	-1,197	-18	-42	+63	-302	-1,496	-1,253	-19	-37	+5	-147	-1,451
1 8	-1,037	-4	-14	+75	-229	-1,209	-1,139	-10	-46	=7	-137	-1,325
1 9	-841	-3	-15	+89	-107	-877	-1,030	-3	-69	+2	-49	-1,149
1 0	-847	+12	-30	+95	-98	-868	-975	-2	-90	-6	-28	-1,101

	Scenario 4						Scenario 5					
1 0	-2,265	+71	-29	+74	+318	-1,831	-1,523	+45	-38	+55	-162	-1,299
1 1	-2,268	+37	-58	+57	+217	-2,015	-1,328	+25	-70	+35	+83	-1,255
1 2	-2,239	+39	+39	+58	+143	-1,960	-1,046	+8	-11	+26	+7	-1,216
1 3	-2,247	+18	+141	+41	+85	-1,989	-1,230	-7	-23	+7	-2	-1,255
1 4	-2,222	+1	+77	+15	+81	-2,048	-1,290	-4	-74	-24	-32	-1,424
1 5	-2,209	+9	0	-2	+138	-2,064	-1,258	+11	-36	-35	-16	-1,334
1 6	-2,157	+6	+3	-15	+149	-2,014	-1,254	-10	-40	-37	-36	-1,377
1 7	-2,100	+3	-5	-12	+123	-1,991	-1,222	-15	-47	-35	-58	-1,377
1 8	-2,041	+5	-12	-16	+210	-1,854	-1,103	+5	-37	-35	-43	-1,213
1 9	-2,008	-2	-13	-16	+247	-1,792	-999	+10	-47	-41	+7	-1,070
1 0	-1,968	-2	-109	-17	+224	-1,872	-1,042	+6	-80	-41	-15	-1,172

Table 18-Base-level projection and projected changes in regional softwood-lumber production, by scenario and region, 1980-
(Million board feet)

	Base							Scenario 1					
Year	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	North	Total	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	Net chang in U. product
1980	8,177	2,825	5,471	5,193	8,804	1,178	31,648	+1,559	+81	+179	+63	+375	+2,25
1981	7,912	2,875	5,558	5,312	9,056	1,188	31,901	+1,934	+63	+137	+50	+309	+2,49
1982	7,682	2,929	5,544	5,329	9,379	1,199	32,062	+2,288	+49	+226	+35	+198	+2,79
1983	7,349	2,904	5,490	5,320	9,716	1,209	31,988	+2,573	+36	+250	+11	+140	+3,01
1984	7,061	2,907	5,542	5,333	10,017	1,220	32,080	+2,751	+55	+104	-4	+76	+2,98
1985	6,752	2,914	5,539	5,362	10,231	1,230	32,028	+2,883	+63	+149	-16	+24	+3,10
1986	6,461	2,918	5,522	5,389	10,446	1,240	31,976	+2,967	+49	+186	-19	-51	+3,13
1987	6,193	2,921	5,536	5,400	10,558	1,151	31,859	+3,142	+48	+160	-7	-103	+3,24
1988	5,961	2,916	5,534	5,415	10,622	1,261	31,709	+3,391	+48	+187	+16	-88	+3,55
1989	5,711	2,919	5,523	5,426	10,625	1,272	31,476	+3,689	+37	+232	+26	-21	+3,96
1990	5,545	2,916	5,570	5,569	10,665	1,282	31,547	+3,792	+39	+155	-85	-85	+3,81

	Scenario 2						Scenario 3					
Year	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	Net change in U.S. production	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	Net change in U.S. producti
1980	+1,014	+6	-1	-22	-133	+864	+1,426	+71	+61	+69	+273	+1,90
1981	+1,365	-2	+1	-47	-175	+1,142	+1,829	+64	+87	+47	+223	+2,25
1982	+1,565	-27	+50	-30	-231	+1,327	+2,141	+51	+187	+40	+120	+2,53
1983	+1,789	+3	+152	+30	-428	+1,546	+2,437	+39	+180	+34	+8	+2,69
1984	+1,987	+8	+158	+71	-534	+1,690	+2,623	+42	+124	+48	-109	+2,72
1985	+2,261	+12	+163	+92	-551	+1,977	+2,720	+51	+166	+51	-135	+2,85
1986	+2,580	+16	+212	+100	-538	+2,370	+2,798	+48	+172	+67	-202	+2,88
1987	+2,864	+38	+173	+117	-528	+2,664	+2,882	+52	+168	+85	-221	+2,96
1988	+3,217	+54	+211	+132	-431	+3,183	+3,072	+67	+155	+94	-222	+3,16
1989	+3,604	+57	+210	+149	-254	+3,766	+3,238	+80	+124	+96	-123	+3,41
1990	+3,775	+75	+183	+19	-186	+3,866	+3,421	+80	+87	-43	-60	+3,48
	Scenario 4						Scenario 5					
1980	0	+125	+211	+120	+680	+1,074	+1,507	+76	+154	+77	+341	+2,15
1981	0	+115	+200	+107	+581	+1,003	+1,891	+65	+120	+60	+290	+2,42
1982	0	+125	+341	+119	+489	+1,074	+2,218	+49	+198	+56	+162	+2,68
1983	0	+114	+498	+107	+367	+1,086	+2,525	+42	+189	+35	+101	+2,89
1984	0	+111	+430	+89	+316	+946	+2,719	+55	+123	+3	+43	+2,94
1985	0	+129	+344	+85	+368	+926	+2,852	+76	+173	-4	+43	+3,14
1986	0	+130	+362	+88	+401	+981	+2,914	+58	+169	-1	+13	+3,15
1987	0	+129	+368	+115	+397	+1,009	+2,989	+51	+163	+9	-25	+3,18
1988	0	+136	+371	+139	+491	+1,137	+3,185	+74	+175	+22	-31	+3,42
1989	0	+138	+395	+170	+556	+1,259	+3,347	+80	+161	+28	+16	+3,63
1990	0	+143	+280	+67	+549	+1,039	+3,361	+75	+117	-89	+3	+3,46

ble 19--Base-level projection and projected changes in regional softwood-plywood production, by scenario and region, 1980-90
illion square feet, 3/8-inch basis)

	Base							Scenario 1					
ar	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	North	Total	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	Net change in U.S. production
80	8,480	1,022	619	950	9,028	59	20,158	+653	-55	-189	-3	-153	+253
81	8,597	1,051	620	965	9,174	60	20,467	+721	-95	-188	-23	-146	+269
82	8,639	1,053	622	987	9,327	61	20,689	+751	-96	-188	-37	-130	+300
83	8,650	1,084	656	1,012	9,478	62	20,942	+794	-123	-199	-42	-132	+298
84	8,671	1,123	686	1,055	9,623	63	21,221	+838	-138	-207	-60	-140	+293
85	8,664	1,171	715	1,099	9,765	64	21,478	+870	-153	-205	-71	-136	+305
86	8,634	1,217	746	1,151	9,913	65	21,726	+905	-149	-209	-90	-128	+329
87	8,611	1,259	779	1,205	10,072	66	21,992	+925	-148	-200	-105	-137	+335
88	8,551	1,304	807	1,274	10,208	67	22,211	+943	-150	-183	-152	-123	+335
89	8,512	1,356	834	1,350	10,331	68	22,451	+938	-146	-184	-193	-108	+307
90	8,476	1,405	859	1,421	10,463	69	22,693	+902	-144	-180	-221	-70	+287

	Scenario 2						Scenario 3					
ar	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	Net change in U.S. production	Douglas-fir	Pacific Northwest-East side	Pacific South-west	Rocky Mountain	South	Net change in U.S. production
80	+1,392	-36	-136	+2	-163	+1,059	+683	-86	-133	-2	-166	+296
81	+846	-79	-159	-3	-189	+416	+735	-119	-132	-18	-161	+305
82	+940	-79	-160	+2	-219	+484	+810	-128	-133	-35	-154	+360
83	+989	-109	-192	+1	-204	+485	+852	-151	-165	-45	-159	+332
84	+993	-120	-196	-18	-205	+454	+898	-168	-169	-70	-157	+334
85	+1,013	-128	-195	-41	-189	+460	+921	-174	-172	-108	-153	+314
86	+1,040	-134	-200	-68	-157	+481	+970	-177	-174	-151	-140	+328
87	+1,032	-138	-201	-75	-165	+453	+1,010	-172	-179	-176	-142	+341
88	+1,028	-136	-205	-75	-155	+457	+1,048	-180	-177	-191	-126	+374
89	+962	-138	-204	-69	-133	+418	+1,048	-192	-173	-211	-99	+373
90	+930	-143	-191	-53	-120	+423	+984	-190	-154	-216	-97	+327

	Scenario 4						Scenario 5					
80	+1,049	-105	-248	-54	-223	+419	+659	-60	-155	-10	-148	+286
81	+1,230	-168	-302	-73	-237	+450	+737	-83	-171	-35	-166	+282
82	+1,390	-188	-332	-98	-281	+491	+769	-91	-171	-50	-145	+312
83	+1,538	-217	-384	-120	-272	+545	+843	-117	-187	-57	-147	+335
84	+1,609	-259	-412	-156	-271	+511	+857	-140	-187	-78	-157	+295
85	+1,673	-276	-440	-194	-284	+489	+882	-149	-189	-91	-152	+301
86	+1,837	-286	-469	-243	281	+558	+931	-160	-190	-106	-147	+328
87	+2,066	-293	-500	-294	-323	+656	+969	-160	-193	-123	-149	+344
88	+2,323	-302	-527	-360	-319	+815	+1,001	-158	-193	-153	-134	+363
89	+2,529	-322	-573	-430	-302	+902	+999	-158	-192	-187	-105	+357
90	+2,732	-338	-597	-496	-297	+1,004	+1,001	-159	-190	-216	-88	+348

Discussion

We again emphasize that the results of the sensitivity analysis should be viewed as general indicators of the responses of U.S. markets for softwood construction materials to a change in U.S. log export policy rather than predictions of what these reponses would be. We have simulated the responses of U.S. markets to a ban on log exports given assumed Japanese responses to the change in U.S. export policy. Under scenario 1, we assumed that Japan would purchase from the United States the lumber equivalent of log-export volume that would have been exported and that Canada would not expand sales of softwood lumber to Japan. Under scenario 2, we assumed that Japan would somehow turn to sources of construction materials other than North America. Under scenario 3, we assumed that Japan would purchase from Canada the lumber equivalent of U.S. log-export volume and that U.S. exports of softwood lumber would not increase. Under scenario 4, we assumed that Japan would purchase from the United States the lumber equivalent of log-export volume, that Canadian sales to Japan would not expand, and that lumber-processing capacity would not expand in the Douglas-fir region. Under scenario 5, we assumed that Japan would purchase from the United States half of the lumber equivalent of log-export volume and half from Canada.

Because historical precedent is lacking because of the many possible Japanese responses to a ban on U.S. softwood-log exports, the basis for predicting how Japanese importers and consumers might respond to a change in export policy is limited. Intuitively, one would expect attempt to make the best of available sources of construction materials as replacements for logs that would have be imported from the United States. Availab information on alternative sources of supply to meet Japanese needs for construction materials suggests that Japan would have to increase the use of mater from all sources. Availability of the equivalent of 4.42 billion board feet o softwood lumber from sources other than North America is uncertain. The degree increased use of construction materials from any one source remains a matter of conjecture.

We emphasize that the potential response of U.S. softwood-stumpage owners to a ba on log exports remains another area of uncertainty in the attempt to simulate t effects of the change in policy on U.S. markets. With the exception of scenario which assumes that no new capacity would constructed in the log-exporting regions, we have assumed that U.S. stumpage owner and lumber processors would respond in t future as they have in the past to chang in stumpage and end-product prices. How stumpage owners, especially in the Dougl fir region, might respond to a change in log-export policy remains a matter of conjecture. Our simulation of market responses under scenario 4 points out fo U.S. softwood markets the implications o lack of capacity to respond in the log-exporting regions.

ithin the United States, our sensitivity nalysis points out that the impacts of a an on log exports would be concentrated in he Douglas-fir region, as expected. For xample, in 1990, a ban would increase rofits from timber processing there by ver $300 million per year, regardless of hat scenario is assumed (table 20). In able 20, processors are defined as producers of softwood lumber and plywood. As a esult of the increased competitiveness of rocessors in this region, profits from rocessing would generally decline in other .S. supply regions.

le 20--Projected effects of a ban on softwood-log exports on U.S. nsumers and on stumpage producers and log processors by U.S. supply ion and scenario, 1990[1] (Million dollars)

	Scenario				
	1	2	3	4	5
nsumers	-105.2	-247.6	-111.1	-65.9	-66.8
ocessors, by region:					
uglas-fir	+322.0	+333.7	+308.7	+548.8	+325.4
cific Northwest-East Side	-7.4	-5.1	-11.1	-19.4	-9.1
cific Southwest	-.1	-2.7	-18.7	-15.3	-16.5
cky Mountain	-6.5	-6.2	-11.3	-19.7	-8.4
uth	-34.5	-53.4	-48.6	-73.1	-34.2
Total	+220.6	+229.7	+166.1	+418.4	+204.4
mpage producers, by region:					
uglas-fir	-482.8	-547.5	-537.3	-970.5	-550.9
cific Northwest-East Side	-7.6	+1.4	-1.1	+2.2	+3.6
cific Southwest	-15.1	-16.2	-28.1	-25.3	-24.0
cky Mountain	-3.6	-70.1	-2.2	+20.6	-3.7
uth	-11.4	-27.1	-9.1	+66.6	-.8
Total	-520.5	-659.5	-578.0	-906.4	-575.7

All effects were calculated using methodology described in Adams et (1977).

The increase in profits from processing in the Douglas-fir region in part would be at the expense of stumpage producers there. As shown in table 20, the amount of money spent for stumpage would decline by $483 million. Reductions in stumpage revenues in other regions would be relatively minor by comparison. In total, stumpage producers would generally lose over $520 million in revenues after a ban on log exports.

Expenditures by consumers for softwood lumber and plywood would decline under the terms of each scenario, ranging from $65,920,000 for scenario 4 to $247,584,000 for scenario 2. This change in consumer expenditure again emphasizes the need for capacity to expand in the log-exporting regions and the need for Japan to turn to all possible sources of construction materials if U.S. end-product prices are reduced by a ban on softwood-log exports.

The sensitivity analyses and review of domestic and foreign supplies and demands for softwood construction materials discussed in this paper provide the basis for the following general conclusions about the impact of the export and import of raw logs upon domestic timber supplies and prices.

Conclusions

- With the exception of softwood-lumber imports from Canada, the United States is self-sufficient in softwood construction materials.

- The impacts of log exports on domestic timber supplies and prices over the past decade are masked by shifts in the variables that determine supplies and prices in domestic softwood markets.

- Japan will continue to be the primary export market for U.S. softwood construction materials during the 1980's.

- The impacts of a ban on log exports on supplies and prices of domestic timber would depend primarily on Japanese responses to the change in policy and on the responses of U.S. stumpage owners and timber processors. These responses are sources of uncertainty that will continue.

- Export markets for U.S. softwood construction materials appear relatively stable during the 1980's. The primary uncertainties are the number and types of housing starts in Japan and the market potential for U.S. softwood lumber if Japan adopts North American construction techniques. Cycles in foreign demands will continue to result in fluctuations in export-sales volumes and prices.

- Domestic rather than export markets have been and will remain the driving force behind U.S. markets for softwood construction materials during the 1980's. The importance of domestic markets compounds analytical problems in attempting to assess the impacts of log exports upon supplies and prices of domestic timber. Even with relatively stable demands projected for U.S. exports of softwood construction materials, real prices for softwood lumber in the United States in 1990 might be as much as 29 percent higher than in 1980 and for softwood plywood, 22 percent higher.

- A ban on U.S. log exports would lowe softwood-lumber prices in the United States only if capacity expanded significantly on the west coast and onl Japan turned to sources of construct materials other than softwoods from America. If Japan could obtain from sources other than North America the equivalent of the construction mater that would have been recovered from logs, softwood-lumber prices in the United States would be reduced by le than 2 percent. The decrease in pric would also be contingent on expanded production of softwood lumber in the exporting regions. The projected ris real softwood-plywood prices in the United States would generally be off by less than 4 percent if log export were banned.

- The Japan-Canada-U.S. trade triangle softwood logs and lumber limits the effect of a ban on export of U.S. so wood logs on U.S. softwood-lumber supplies and prices. Any expansion o U.S. softwood-lumber supplies destine for the domestic market after a ban would tend to be offset by reduced imports from Canada. Any expansion o U.S. lumber exports to Japan would te to be countered by increased imports from Canada.

- Significant expansion of Canadian exports of softwood lumber to Japan after a ban on U.S. log exports woulc tend to reduce Canadian shipments to United States.

- Lumber-processing capacity in the Uni States after a ban on log exports wou probably expand by less than the lumb equivalent that Japanese processors would have recovered from U.S. logs. Domestically produced softwood lumber would be diverted from the U.S. marke stimulating imports from Canada if Ja tried to purchase the lumber equivale of U.S. logs from the United States.

- Annual consumption of softwood lumber in the United States would generally be affected by less than 500 million board feet after a ban on softwood-log exports, regardless of what response is assumed for Japanese attempts to compensate for the loss of U.S. softwood logs. The responses of producers in other U.S. supply regions and the response of Canadian imports tend to limit the impact of log-export policy on lumber consumption in the United States.

- The U.S. balance of trade would generally be negatively affected by a ban on softwood-log exports.

- The impacts of a ban on softwood-log exports on stumpage prices would fall most heavily in the Douglas-fir region. Lumber and plywood processors there would generally gain in competitive position relative to processors in other regions. Stumpage owners--public and private--in this region would lose net revenue from the change in policy.

- Timber harvest in the United States would generally decline by over 1 billion board feet, regardless of the interactions of markets after a ban on log exports.

- Total timber harvest in the log-exporting regions of the west coast after a ban on softwood-log exports would generally decrease, especially if processing capacity did not increase or if Japan turned to sources other than North America for construction materials.

- Assuming no increase in lumber-processing capacity in the log-exporting regions and assuming no increase in U.S. exports of lumber, the magnitude of the resulting decline in stumpage prices in the log-exporting regions after a ban on log exports suggests that some additional processing capacity would be constructed, but how much is uncertain.

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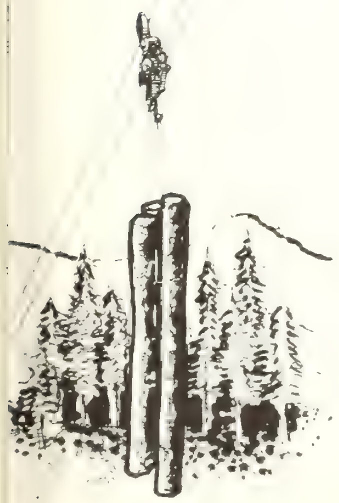

Appendix: The Simulation Model

The simulation model consists of sets of supply and demand relations (fig. 7). Demand equations were developed for lumber and plywood in each of seven demand regions; supply equations were developed for nine regions including Canada. The cost of transporting wood products from supply to demand regions was considered. Estimates of output of pulpwood, log exports, fuelwood, and miscellaneous products in each supply region were derived from projections of consumption and trade in these products conducted outside of the model. The demand for stumpage in each supply region was derived from supplies of products (lumber, plywood, pulpwood). Supplies of stumpage consist of public harvests set by policies of Federal and State agencies, and private supply, which are responsive to both stumpage price and inventory volumes available. Inventory volumes by ownership and region are projected over time using the TRAS model (Larson and Goforth 1974). In each year of the simulation, the several supply-and-demand equations interact in the several markets to determine market clearing prices and volumes consumed and produced for all products and stumpage in all regions.

The model simulates the effects of a ban on log exports through a change in log-export volume in the stumpage sector depicted in figure 7. Log-export volumes were reduced to zero for the Douglas-fir and Pacific Southwest regions. This has the effect of changing the demand for stumpage in these two regions. For each of the two regions, the change in stumpage demand interacts with other components of the stumpage sector and with the supplies and demands that form the final product sector.

Lumber exports are treated in the model as a shift in lumber demand for each region. Thus, the lumber demand of each region depicted in figure 7 includes lumber exports. Lumber-export volumes, however, are determined outside of the model and do not interact with its other components.

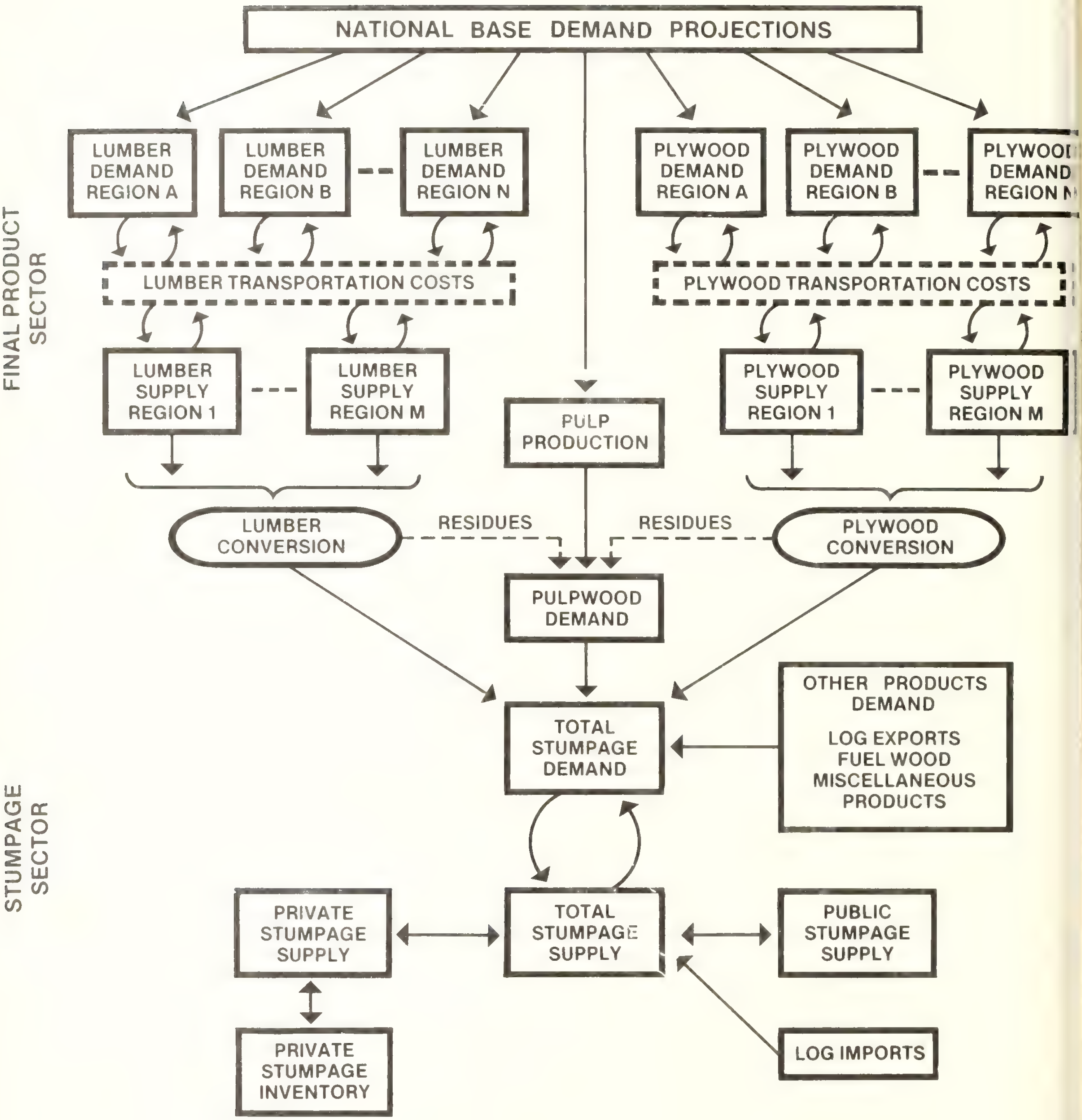

Figure 7.--Major interactions in the timber-assessment market model. Curved arrows indicate where supply and demand interact to determine prices. A straight arrow with a single head indicates that variables are exogenous or determined outside the model. The straight arrows with two heads in the stumpage supply sector of the model indicate an endogenous relation between the variables in the two boxes connected by the arrow. The relation, however, is not one that determines market prices directly; all prices are determined by the interaction of supply and demand.

Darr, David R., Richard W. Haynes, and Darius M. Adams. 1980. The impact of the export and import of raw logs on domestic timber supplies and prices. USDA For. Serv. Res. Pap. PNW-277, 38 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Reviews U.S. foreign and domestic markets for softwood construction materials, giving special consideration to trade patterns among Japan, Canada, and the United States. For alternative assumptions about market responses to a ban of U.S. softwood log exports, displays impacts on selected measures of U.S. softwood stumpage, lumber, and plywood markets.

KEYWORDS: Import/export (forest products), markets (internal), trade policy, supply/demand (forest products).

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Research Paper
PNW-278

November 1980

The Standley Allotment: A History of Range Recovery

Gerald S. Strickler and Wade B. Hall

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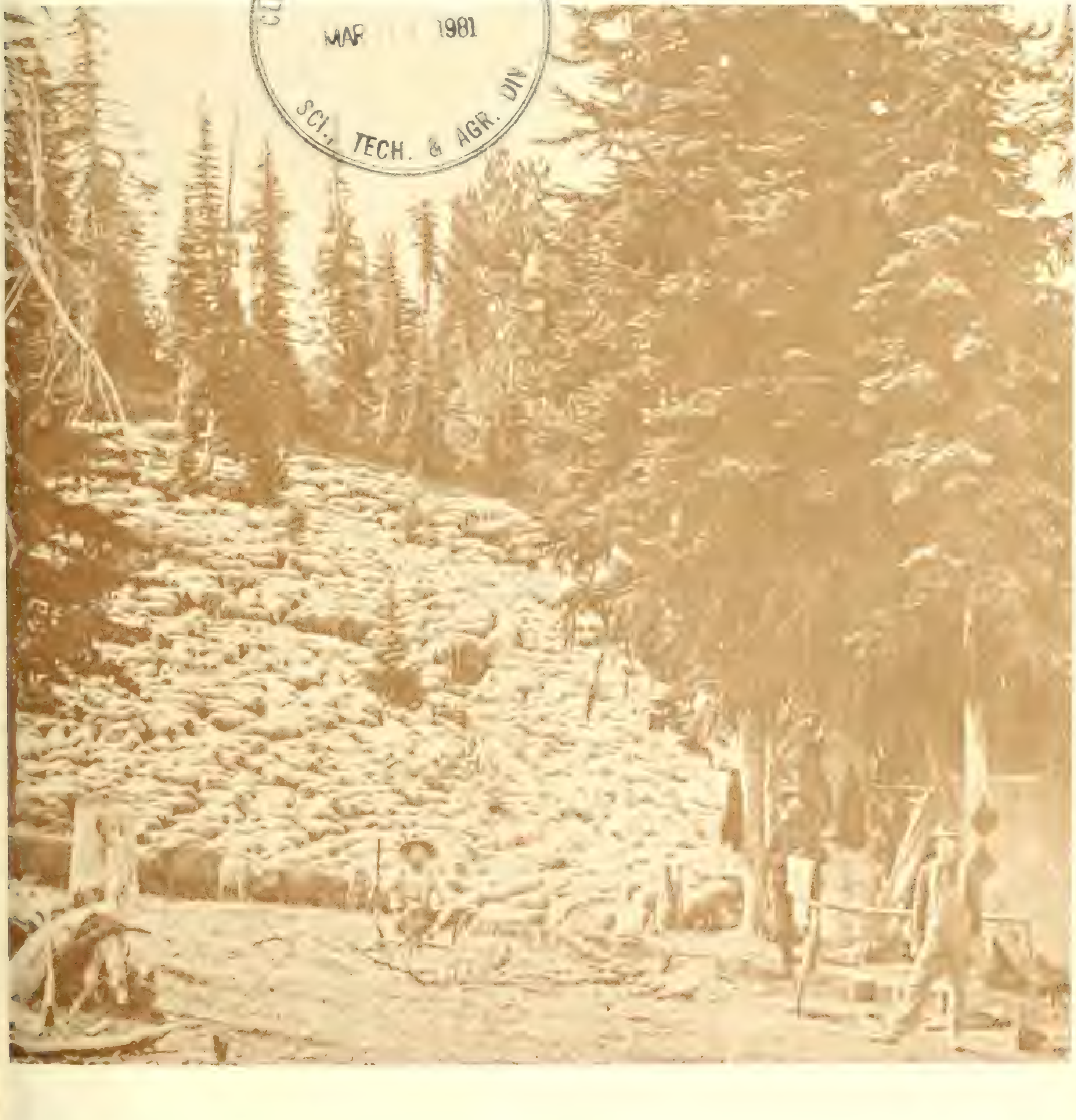

Authors

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Wade B. Hall (retired) was formerly staff officer, Wallowa-Whitman National Forest, Baker, Oregon.

Metric Equivalents

1 mile (mi) = 1.61 kilometers (km)
1 foot (ft) = 0.3048 meter (m)
1 inch (in) = 2.54 centimeters (cm)
1 square foot (ft^2) = 0.0929 square meter (m^2)
1 acre = 0.4047 hectare (ha)
Degrees Fahrenheit (°F) = 1.8 degrees Celsius (°C) + 32°

Cover photo: A sheep camp and bedground on the Standley allotment, 1907.

The Standley Allotment: A History of Range Recovery

Reference Abstract

Stckler, Gerald S., and Wade B. Hall. 190. The Standley allotment: A hiory of range recovery. USDA For. Sev. Res. Pap. PNW-278. 35p., illus. Pa. Northwest For. and Range Exp. St, Portland, Oreg.

Oe of the first range research programs on National Forest lands was cducted by Dr. Arthur W. Sampson n he Wallowa Mountains, Oregon, beween 1907 and 1911. This paper eews the historical perspective of ar the basic range management prciples and practices developed rch Sampson's studies as well as hland and grazing management of hstudy area to 1980. Plant successio and range improvement from the deleted conditions prevalent in 1907 ar discussed and documented by phtographs between 1955 and 1976.

Kewords: Range management, hiory (range research), revegetation rage) succession, subalpine ranges, *Fetuca viridula*, grazing damage.

Research Summary

Beveen 1907 and 1911, Dr. Arthur W. Saipson conducted one of the Forst Service's first range research prgrams on the subalpine grsslands of the Standley allotment n e Wallowa Mountains of eastern Orgon. Excessive grazing by sheep, benning about 1880, had resulted in sere deterioration of vegetation, so and watershed resources. Only remnants remained of the once domina green fescue, an important forge grass. Much of the grassland wa eroding and barren. Sampson recrded these conditions and his expemental studies with photographs. Where sufficient green fescue plants remained, Sampson deemed it possible to restore the productivity of the grasslands through natural reseeding. His 1st-year study of the seedling ecology of major species suggested that a deferred grazing system would allow the fescue to flower, set seed, and become established in the depleted communities. Three areas of the Standley allotment, those in the poorest condition, were set aside and grazed the last fifth of the grazing season for 4 years. Sampson studied and compared their recovery with that of other areas, both protected and grazed season-long.

The deferred grazing system worked well. Green fescue seedlings became established and matured, range condition had improved, and it was not disadvantageous to sheep. Similar deferred systems were used on several allotments in the Wallowa Mountains, and Sampson recommended their use on other badly depleted ranges in the Western United States.

On barren sites where natural revegetation was unlikely, Sampson conducted a 5-year study of reseeding with introduced grasses. As part of a more extensive study in the Western United States, his objective in the Wallowa Mountains was not only to restore productivity but also to determine either the factors necessary to insure seeding success or the reasons for failure on subalpine sites. He experimented with planting methods and spring and fall seeding and observed the growth and adaptability of the seeded species. The seedlings were successful; however, their long-term survival in the subalpine environment seemed unlikely. Sampson published some reseeding guidelines based on this work; the guidelines are still used.

As a result of Sampson's work, livestock numbers were reduced on the range and various land and livestock management practices, including deferred grazing and non-use, were initiated to promote recovery of the range.

Between 1955 and 1976, quadrat studies were made and photographs were retaken to record and illustrate the recovery of vegetation. In 1976, vegetation cover had greatly increased (to 60 percent), and green fescue had regained or shared dominance where sufficient topsoil, uneroded or in remnant pedestals, had remained in 1907. Sites that had been severely eroded or barren in 1907, showed variable recovery. Some had a fair to good cover (to 40 percent) of vegetation dominated by secondary species; green fescue cover has only recently begun to increase in these communities. Other sites barren in 1907 remained in that condition because of their location, continued overgrazing, or because frost heave and summer drought prevented establishment of seedlings. Where Sampson reseeded introduced species, only native species were found. Cover was fair (30 to 40 percent), and both secondary species and green fescue dominated, the latter where it was present in 1907.

Although recovery since 1907 was apparent, the early depletion of vegetation and soil erosion essentially modified the grassland habitats and regulated the rate and amount of recovery. The plant communities were in a variety of secondary successional stages. No communities had recovered to green fescue climax.

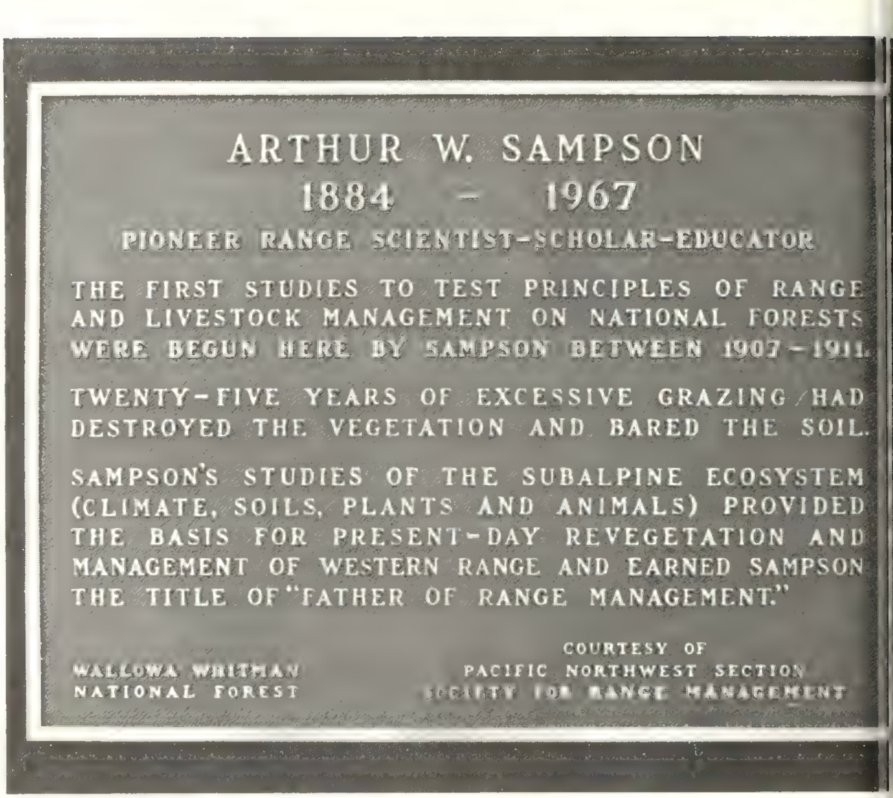
Preface

The Wallowa Mountains in northeast Oregon are an area of rugged scenic beauty well known by hikers, back packers, trail riders, and hunters. The mountains are also important as a watershed to surrounding municipalities and for irrigation and hydroelectric facilities in the lower valleys. Furthermore, they supply abundant habitat and summer grazing for game animals, particularly deer and elk, and for domestic livestock.

Watershed and range conditions in the Wallowa Mountains, however, were poor in 1900. The scene was one of deterioration caused by 20 years of excessive grazing by domestic cattle and sheep. Dr. Arthur W. Sampson, a young ecologist in the Bureau of Plant Industry in Washington, D.C., was sent by the Forest Service in 1907 to determine how to stop the deterioration and improve conditions. The results of his 5-year study of subalpine ranges on the Standley allotment led to early development of many range management principles and practices in use today.

The pioneering work of Arthur Sampson and the subsequent recovery of the ranges provided stimulus for the study reported here. This paper is respectfully dedicated to his memory.

Dr. Sampson, who died on February 7, 1967, was honored on July 29, 1976, by the dedication of a plaque on a stone monument overlooking one of his research areas near Standley Spring.



ARTHUR W. SAMPSON
1884 – 1967
PIONEER RANGE SCIENTIST-SCHOLAR-EDUCATOR

THE FIRST STUDIES TO TEST PRINCIPLES OF RANGE AND LIVESTOCK MANAGEMENT ON NATIONAL FORESTS WERE BEGUN HERE BY SAMPSON BETWEEN 1907–1911.

TWENTY-FIVE YEARS OF EXCESSIVE GRAZING HAD DESTROYED THE VEGETATION AND BARED THE SOIL.

SAMPSON'S STUDIES OF THE SUBALPINE ECOSYSTEM (CLIMATE, SOILS, PLANTS AND ANIMALS) PROVIDED THE BASIS FOR PRESENT-DAY REVEGETATION AND MANAGEMENT OF WESTERN RANGE AND EARNED SAMPSON THE TITLE OF "FATHER OF RANGE MANAGEMENT."

WALLOWA WHITMAN
NATIONAL FOREST

COURTESY OF
PACIFIC NORTHWEST SECTION
SOCIETY FOR RANGE MANAGEMENT

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CP = camera points.

ntroduction

he Standley allotment in Oregon's allowa Mountains (fig. 1) looms rge in the history of rangeland search and management in the estern United States. It was in the balpine grasslands of this grazing otment in the early 1900's that Dr. thur W. Sampson[1] began one of the st research programs on National rest lands to test new ideas and inciples of range management.

the Wallowas, as in many parts of e West, excessive grazing by mestic sheep and cattle had maged or were damaging the nges almost beyond repair. Soil erosion was extensive, and the desirable age plants were greatly reduced or, some areas, eliminated. Parts of e range had become "practically lueless for grazing purposes" ampson 1908, p.7). Information on oper management of these asslands was needed to restore getative cover and productivity for th watershed protection and estock forage.

mpson's studies on the Standley otment between 1907 and 1911 not ly provided guidelines for restoration of subalpine grasslands but also ovided significant contributions to e infant science of range management. He continued his research on balpine ranges in Utah and subsequently taught range ecology and nagement at the University of lifornia, Berkeley. For more than 50 ars, in his many papers and textoks, he often used the research ults and photographs from the llowa Mountains to emphasize ges of plant succession and range terioration and improvement.

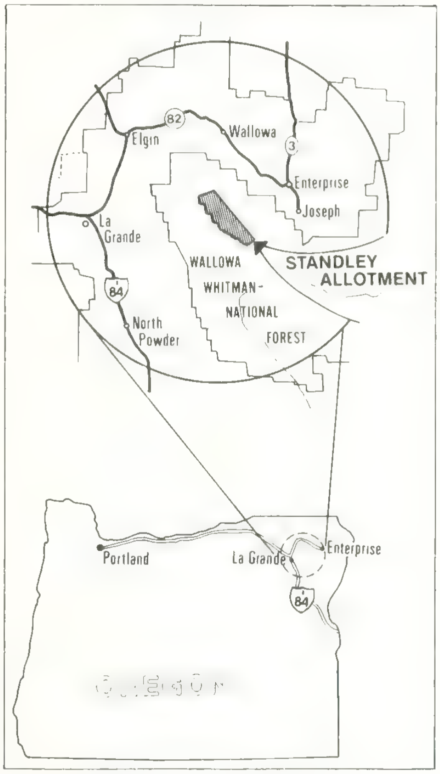

Figure 1. *The Standley allotment in northeast Oregon.*

Sampson revisited the Standley allotment in 1955, at age 71, to observe the changes that had taken place. Some sites visible in six original photographs were rephotographed and notes were made on the presence and amount of plant species. We continued this process intermittently until 1976. During this time, 10 more of the original photograph sites were located and rephotographed. The photograph series, and the accompanying plant data, provide the basis for this paper, which is a story of Sampson's studies between 1907 and 1911, and the changes and recovery observed between 1955 and 1976, 48-69 years later. Unfortunately, Sampson's original quadrat data have been lost, and his assessment of the recovery he observed in 1955 was not recorded. We therefore make use of data and photograph captions available in his reports, manuscripts, and publications of the early studies, and the notes taken by those who accompanied him in 1955. We often quote from his early papers to narrate the story.

Need for Research

The grazing capacity of Western mountain rangelands was seriously depleted by 1907 as a result of overstocking during the "free-for-all" (Sampson 1913a, p.2) grazing period that followed settlement in the mid-1800's. Sheep and cattle had repeatedly removed most of the plant growth early in the growing season year after year. This lowered the vitality of the plants and their ability to produce viable seed (Sampson 1913a).

In 1889 a preservationist group, led by John Muir, pressed for complete closure of the high mountain lands in the Pacific Northwest to sheep use (Wolfe 1945). The group not only deplored the damage to vegetation by sheep and the subsequent deterioration of the watersheds but also considered sheep to be a blight on the landscape. But convervationists, later including Gifford Pinchot, considered such closures impractical from the standpoint of the livestock industry and thought that the grazing lands could be improved if brought under governmental management (Nash 1973, Rakestraw 1958).

At the request of the preservationist group, 4.5 million acres along the Cascade Range were set aside in 1893 as Forest Reserves and closed to sheep grazing. Pressure by stockmen soon reinstated sheep use, yet, following an 1897 study of range conditions in the Cascade Reserve (Colville 1898), it was evident that regulation of grazing would be necessary. In 1899, the stockmen and forest officials decided to begin a permit system; individual owners would graze designated range allotments and would be charged a fee of $5 per 1,000 head (Rakestraw 1958). But range conditions continued to decline because of sheep numbers (2,500,000 in Oregon in 1897) and improper management of land and livestock.

---

[1] ampson is briefly identified in the face. For a detailed account of Dr. mpson's life and work, read the graphy (Parker et al. 1967) prepared by close friends, associates, and former dents following his death.

Study Areas

These controversies and actions were closely followed by stockmen who used the high mountain summer ranges in northeastern Oregon. In contrast to the Cascade Reserve, this area was still public domain and had a longer history of uncontrolled grazing (Colville 1898). The grazier who got there first got the forage. The result of such exploitation was the continuing decline in sheep numbers. Many ranges were

> ...so much reduced in carrying capacity that they have been rendered practically valueless for grazing purposes, and the original palatable plants...have been succeeded by weedy annuals or by perennial species that are of little or no forage value (Sampson 1908, p. 7).

In 1901 Oregon stockmen endorsed the proposed establishment of the Forest Reserves in northeast Oregon (Minto 1902); they were beginning to accept the fact that range forage was limited and that some regulation of grazing similar to that done in the Cascade Reserve would be to their interest if carrying capacities were to be increased. As Sampson stated,

> Owing to the great importance of the summer range to the grazing industry in this community,...[the Wallowa National Forest]...the question of range improvement was strongly agitated by stockmen. Finally the Government was called upon to make a critical study of the ranges and gather such information as might be of value in finding some practical means of improving the existing conditions (Sampson 1908, p. 7-8).

When Sampson arrived in the Wallowas in the spring of 1907, he had these objectives: (1) continue research in reseeding cultivated forage plants on "grazed-out" areas, (2) study the ecology of the native forage plants and plant communities of the major summer range types, and (3) from these studies, develop grazing systems that would improve range condition. Because the green fescue[2] grasslands in the Hudzonian or whitebark pine zone[3] supported

> ...most of the sheep permitted in the Wallowa Forest during the summer growing season...[and]...on account of the demands made upon this desirable range and because of the character of the forage, the Hudzonian zone has suffered more serious depletion than any other, and it was here that the most intensive study of revegetation was made (Sampson 1914, p. 96).

Sampson selected two subalpine grasslands for intensive study, one near Standley Spring and the other in Sturgill Basin. They were on the Standley allotment which is now located in the northwestern portion of the Eagle Cap Wilderness. Wilderness lands became the center of the summer sheep range in the 1880's with large introductions and buildup of sheep numbers (Wentworth 1948). By the mid-1890's, several hundred-thousand sheep and cattle followed the melting snow to the high summer range and stayed there until snowed-out in late September. Range deterioration eventually forced a reduction in sheep numbers; only 252,000 ewes with lambs were permitted to graze on the newly established Wallowa National Forest in 1906 and 166,000 in 1907,[4] the year Sampson began his studies.

Livestock use on Standley allotm (and the two study sites) before 1 is unknown but discussions with timers indicated that the allotme was heavily grazed by both sheep cattle prior to the establishment the Wallowa National Forest in 1 The known graziers (William Sher J.D. Standley, J.H. Dobbin, Georg Schaut, and John Goebel) annual grazed about 1,000 head of cattle 10,000 ewes on the allotment. Th followed the common practice wh ranges were first "topped"[5] with ewe-lamb bands. After the lambs were removed, dry ewe bands we back, regrazed the allotment, and took the remaining herbage. They were kept on the area until the sn drove them out. Although the cat generally grazed the lower canyo slopes, they often climbed to the subalpine grasslands. This practi produced the depleted range con tions that Sampson observed at Standley Spring and Sturgill Basi 1907.

The two study sites, 6 miles apar large grasslands distinctly subalp in character and climate at about 7,400 feet. Vegetation is typical o lower subalpine where spruce-fir lodgepole pine forests give way t tensive open parklands interspers with individual trees and patches subalpine fir, Engelmann spruce, whitebark pine.

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[2] Scientific names are listed in the appendix.

[3] Sampson's Hudzonian or whitebark pine zone (Sampson 1909, p. 9-10) equates with the subalpine fir zone (Franklin and Dyrness 1973).

[4] Tucker, Gerald J. 1955. A history of the Wallowa National Forest. 286 p. Unpublished manuscript on file at Range and Wildlife Habitat Laboratory, La Grande, Oregon.

[5] Grazed for just the best forage; i.e., leaves, succulent plants, etc.

e short summer season is cool and
with 4-6 inches of precipitation
ing July through September.
nters are long, cold, and wet. The
ow, which reaches an average max-
um depth of 8 feet,[6] accounts for
st of the estimated 40 inches of
ual precipitation.

gust, the warmest month, has an
rage daily temperature of 60°F,
daily high and low temperatures
be extreme; Sampson recorded a
h temperature of 91°F in 1909 and
ed that frosts could occur at
time. January, the coldest month,
mean daily temperatures of about
F.

nd is an important factor in the
alpine environment. It is com-
nly more pronounced and constant
n at lower elevations, greatly af-
ting soil and air temperatures, soil
isture, and snow deposition and
oval. Thus it strongly influences
cies composition and distribution
plant communities. On depleted
ssland sites, summer winds easily
ove or redistribute the dry surface
ls.

The basalt-derived soils of the study area are medium to fine textured and contain loess and volcanic ash that were aerially deposited about 6,000 years ago. This combination of materials forms rich soils with high water holding capacity but which also are friable and loose, characteristics that cause surface layers to dry quickly and erode when the protective plant cover is depleted. Even where topography is gentle, much bare rock is evident. Some rocky areas are a natural phenomenon of the mountain environment, but some became exposed as wind and water removed the surface soil of the depleted grasslands.

Sampson listed plant species that occurred on the depleted grasslands. The most abundant, prior to deterioration, was green fescue which gave "...character to the landscape... [and was]...preeminent in importance among the forage plants of the entire range" (Sampson 1908, p. 10). But this grass had been virtually eliminated and replaced by species better adapted to the eroding soils. Of these, western and little western needlegrass[7] and various sedges were most agressive. Sampson noted that needlegrass planted itself, particularly on barren soils subject to higher daytime temperatures than occurred on vegetated sites. The repeated twisting and untwisting of the awn with alternate drying and wetting pushed the seed into the soil, and the backward-turned hairs on the seed then held it in the soil.

Of the sedges, Ross sedge (Sampson's sickle sedge) was particularly abundant:

> ...sickle sedge, a short, wiry weed which is not at all palatable to stock, composed at least nine-tenths of all the seedlings. This plant is very vigorous, has a wide distribution locally, and is adapted to a variety of habitats. It produces an abundance of seeds which matures so early in the season that... [grazing]...does not materially interfere with the seed production, and it perpetuates itself abundantly by offshoots from the rootstalks (Sampson 1908, p. 18).

Of the many forbs, the more common were fernleaf licoriceroot, peregrine fleabane, western yarrow, Cusick speedwell, pokeweed fleeceflower, skyrocket gilia, hairstem groundsmoke, and needleleaf sandwort. These were less preferred as forage, and the ungrazed vigorous plants had flowered, produced abundant seed, and spread over the depleted grasslands. They thus competed for space, nutrients, and moisture with the weakened and continually grazed green fescue.

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[6] on Baldwin, Soil Conservation Service,
erprise, Oregon. Personal communica-
n.

[7] Little western needlegrass (*Stipa occidentalis* var. *minor*) is commonly mistaken for Letterman needlegrass (*S. lettermanii*) which is also abundant in other green fescue grasslands in the Wallowa Mountains (Reid et al., 1980). Our voucher specimens were identified as *S. occidentalis* var. *minor*, thus all "dwarf" *Stipa* encountered were assumed to be this taxa. Sampson (1914) listed *S. occidentalis* and *S. minor* [sic] in his publications.

The Studies: 1907-1911

Natural Revegetation

Sampson determined that it would be essential to study the life cycles of native forage plants if he were to bring about their reestablishment on the depleted grasslands. For this work he constructed small enclosures to compare the reproductive processes of grazed and ungrazed plants. Comparative observations included both the beginning and the period of (1) spring growth, (2) flowerstalk production, (3) seed maturation, viability, and germination, and (4) seedling establishment. Special attention was given to green fescue, but information on all prominent species was needed to determine

> . . . the rate at which plants are invading overgrazed areas, and becoming established on them, the character and composition of this succeeding vegetation, . . . [and] . . . the plants which may eventually predominate under the present conditions . . . (Sampson 1908, p. 12).

Observations were made on 1-m^2 quadrats. On some, the position of every plant was charted. On others, all vegetation was removed to determine establishment rates of invading species. Sampson followed plant succession on these quadrats for 3 years, simultaneously recording air temperature, humidity, precipitation, soil moisture, and evaporation. He considered these the important climatic factors ". . . which determine the rate of movement, character of grouping, and composition of . . ." the developing plant communities (Sampson 1908, p. 13).

Similar quadrats were established on grazed sites to determine losses from trampling and utilization.

At the end of the 1907 grazing season, Sampson confirmed the fact that green fescue was the most valuable forage plant in the Wallowa Mountains. It was the most abundant, palatable forage plant and was "relished" by sheep throughout the grazing season. Furthermore, his later analysis showed that the mature green fescue had 94 percent more protein and 50 percent less fiber than timothy hay (Sampson 1914).

Sampson also found that seed of green fescue and other important forage plants ripened about September 1, but this date varied considerably because the overgrazed plants had poor vigor. Many plants produced seeds of low viability. Consequently, these plants were not reestablishing themselves on the depleted ranges. Most established seedlings were either annuals, which produced abundant seed, or of Ross sedge and the perennial forbs mentioned previously, or of little western needlegrass, California brome, and slender hairgrass, perennial grasses not ". . . greatly relished by stock . . . [and thus] . . . allowed to go to seed" (Sampson 1908, p. 18). Counts on the grazed quadrats showed that moderate grazing by sheep in late summer had resulted in a 33-percent loss of a sparse stand of current-year seedlings (Sampson 1908). Sampson concluded, however, that if ". . . two-thirds of the seedlings survived in good condition after grazing, ample reproduction is assured" (Sampson 1908, p. 19).

With these results, Sampson began to plan a deferred grazing system to reestablish green fescue, possibly developing his ideas from Cotton's (1905) earlier review of the good points of "alternation" and delaying of grazing in pastures. About one-fifth of the summer grazing season remained after the bulk of the green fescue seed crop had matured. He reasoned that if an area of range having one-fifth of the forage needed for one sheep band were closed to grazing to protect a seed crop, sufficient time would remain after the seed had fallen for the sheep to use the forage and, while grazing, plant the seed by their trampling. Removal of leaf tissue after plants had attained growth and food storage would i terfere less with plant vigor, grov and reproduction processes duri the following season than would earlier grazing.

Sampson began deferred grazing studies in 1908 on three areas of Standley allotment—at Standley Spring, Sturgill Basin, and in the cent Bear Creek drainage. Seedli studies indicated that the deferr system would have to be repeate the same areas in 1909 to give th new seedlings an opportunity to develop root systems strong and enough to withstand trampling. A 2d-year deferment would also pe development and dissemination second seed crop in case the on 1908 was poor (Sampson 1909).

The 1908 results were not conclu Although Sampson's data indica that 1907 and 1908 were fairly gc seed years, practically no viable was produced in 1907, and there only a small seed crop in 1908 (S son 1913a). Forage plants were s weakened from past overgrazing seed production and viability wei still low. He concluded that impr ment in the forage stand would ". . . not be known until another season . . . [of deferred grazing] . . passed" (Sampson 1909, p. 28).

The deferred grazing experiment continued in 1909 and the follow information was collected: (1) co ison of seedling stands on the si protected, deferred, and grazed season-long, (2) morphological development of different aged se lings, their moisture requirement and loss of seedlings in relation climatic conditions from early sp to fall, (3) the mode of seedling destruction resulting from moder fall grazing, and (4) the time neec for recuperated forage plants to duce normal, viable seed crops w protected or deferred from grazin reen fescue vigor greatly improved side the ungrazed enclosures. Its over had increased, primarily by llering of small plants, and a atisfactory seed crop was produced. ut only a few seedlings were stablished (Sampson 1914). Conersely, he found good seedling stablishment on grazed range, and corded 2-10 times more seedlings of e important forage plants on derred range than on range grazed eason-long. Sampson (1914, p. 105) erefore concluded "...that if the rage crop is left undisturbed until e seed has ripened...it will prouce as large and as early a seed op the following season as will getation on range not grazed at l."

ampson's study of seedlings owed that shallow rooted (2-5 in) st-year plants suffered losses from ummer drought, competition (where ense), and frost heave in early sumer. In addition, 60 percent or more the remaining seedlings could be st when fall-grazed under the derred system. Losses resulted from e sheep's hooves pruning the surce feeding roots or, in wet soils, essing the plants out of the ground ampson 1913b, 1914).

ere were fewer losses for 2-year-old ants. These plants escaped surface il drought in the summer and frost ave in the fall and spring because eir roots were more extensive and enetrated deeper. In the third growg season, plants were considered ature and usually produced viable ed (Sampson 1913a).

By the fall of 1909, Sampson had concluded that 3 years of protection were required for badly depleted green fescue plants to produce abundant viable seed. He believed, on the other hand, that green fescue grasslands which retained native forage plants not more than 6 feet apart could be improved through deferred grazing systems (Sampson 1914). Although heavy losses of seedlings did occur under moderate deferred grazing, the remaining seedling stand, the improved vigor, and the increased shoot growth of the mature plants were satisfactory evidence that the range was improving.

Sampson continued his observations in 1910 and 1911. In 1912, the deferred grazing system was used on 10 allotments of the Wallowa National Forest, and Sampson made a final tour of the Wallowa Mountains and the Standley allotment to show the results of his work to other Forest Service researchers. The sheep

> ...made fully as good progress as other sheep in allotments not handled under deferred grazing...[and]...in every case the carrying capacity of the range has increased materially, and the best interests of the stock industry seem to call for the adoption of the system generally (Sampson 1914, p. 145-146).

Artificial Revegetation

Sampson's reseeding work was part of a more extensive study begun by the Forest Service and the Bureau of Plant Industry in 1907 throughout the Western United States. The species tested, time of planting, and seedbed treatments were dictated by the design of the overall study. His objective in the Wallowa Mountains was to determine either the factors necessary to insure seeding success or the reason for failure on subalpine sites.

The largest reseeding (20 acres) was near Standley Spring. Originally covered with green fescue, the parkland was almost barren in 1907. Annuals were scattered "in profusion" and Ross (sickle) sedge was the most abundant perennial. Dense cover of relatively unpalatable perennial species occurred only adjacent to springs, seeps, and stream channels (Sampson 1913c). The area was hand-seeded in the fall of 1907 with a mixture of common timothy, redtop, and Kentucky bluegrass. The seed was trampled into the soil by driving a compact band of sheep over the area twice.

The same species, individually and mixed, were seeded on a 5-acre plot at Sturgill where Sampson compared a no-planting treatment (seed broadcast on the surface) with brushing and trampling treatments that covered and pushed the seed into the soil. The reseeded site had been annually used as a bedground. Most of the surface 6-inches of soil had eroded away and, except for a small area of dense green fescue and western needlegrass, was "...bare of vegetation save for a few scattered tufts of...[western]... yarrow..., sedge, and...[little western]... needlegrass..." (Sampson 1913c, p. 12).

He seeded other species and tried other seed planting methods on smaller plots near Standley Spring in the spring and fall of 1908. All reseedings were fenced in 1908 to exclude sheep grazing. Seedling establishment and growth were observed until 1910.

Sampson's studies verified that fall seeding was superior to spring seeding; covering the seed by brushing, harrowing, or trampling resulted in more plants and better establishment than where no treatment was applied; and timothy was the most adapted species of several which had been established.

It was evident that the subalpine environment influenced seedling establishment, growth, and survival. Timothy was essentially the only species remaining in 1910, but studies of its life cycle showed that it was not well-adapted to the short growing season. Individual plants had 50-percent less growth than those grown 3,000 ft lower, root systems were poorly developed, fewer and dwarfed leaves and culms were evident, and smaller seedstalks produced few viable seeds. Sampson concluded that the timothy stands would neither increase nor long persist, particularly under the prevalent grazing methods, and that the 7,300-ft elevation of the Standley Spring and Sturgill Basin reseedings was the maximum at which reseeding should be attempted in the Wallowa Mountains (Sampson 1913c).

Grazing Management: 1911-1980

Wallowa Mountains

Sheep numbers decreased in the Wallowa Mountains following Sampson's work (table 1) mainly because of the lack of forage, but numbers were still too high for the depleted conditions. Overgrazing of many allotments continued until 1940 (Pickford and Reid 1942). Many sheep were still sold by the head, and wool production was a major commodity in the early years. Sheep numbers were, therefore, important to the welfare of sheepmen and, in turn, to the economy of the area. Thus for many years Forest Service personnel felt a stronger responsibility to supply the summer forage needed by sheepmen and their large flocks than they did to their basic responsibility of land stewardship.

Table 1—Sheep numbers on the Wallowa-Whitman National Forest, 1911-1979[1]

Year	Sheep numbers
1906	252,000
1907	166,000
1908	238,800
1911	121,740
1920	61,447
1930	68,876
1940	48,725
1950	12,940
1960	17,462
1970	10,000 (approx.)
1979	10,400 (approx.)

[1] From grazing records, Wallowa-Whitman National Forest. Sheep numbers are for those portions within the original boundaries of the Wallowa and Imnaha National Forests in 1906.

But the Forest Service and sheep
did follow Sampson's recommend
tions and voluntarily began to red
sheep use on some ranges and in
deferred grazing systems on other
(Sampson 1914). They tested this
system against the "old way" to s
if lambs, grazing cured forage on
deferred ranges, lost weight. They
didn't; average weights, extremely
by today's standards, were 58 and
pounds respectively on Septembe

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[8] 1913. Report (letter) by J. Fred McLa
Forest Ranger. Historical grazing file.
Pacific Northwest Forest and Range E
periment Station, Portland, Oregon.

tandley Allotment

eep numbers on the Standley allot-
nt remained about the same for 15
rs (table 2). The numbers in-
ased slightly during World War I
ause the need for additional meat
l wool for the war effort effectively
ted reductions in numbers and
erment of additional range units.

lowing the war, sheep numbers
l sheep use again declined in
ponse to the need to improve
ge conditions. Certain "camps,"
grazing units of the allotment,
e deferred annually. Furthermore,
permittees quit the sheep business
returned their grazing permits to
Forest Service, those acres were
oved from grazing or were added
to adjacent allotments on the basis of need. As a result, the present Standley allotment now embraces 54,493 acres and is grazed by one permittee instead of five.

Sheep numbers again declined in 1935, and this continued until World War II when numbers stabilized. Although sheep numbers have fluctuated widely, they have steadily decreased during the last two decades. There was no use of the allotment in some years. In 1980, the 2,000 sheep grazing the Standley allotment for 3 months represents an 88-percent reduction in sheep use since the turn of the century.

ble 2—Annual livestock use of the Standley allotment, 1890-1980[1]

iod	Number of sheep	Average number of months used	Sheep months
1 0-1905	10,000 (+1,000 cattle)	3.75	52,500
1 6-10	10,000	4.00	40,000
1 1-20	10,500	3.64	38,252
1 1-30	7,750	3.93	30,478
1 1-40	6,630	4.12	27,329
1 1-50	3,580	3.41	12,229
1 1-60	2,690	3.48	9,367
1 1-70	2,730	3.41	9,313
1 1-75	2,300	3.08	7,093
1 0	2,000	3.00	6,000

[1] ata between 1890 and 1910 from interviews with stockmen; from 1911 to 1975 n the files, Wallowa-Whitman National Forest; and 1980 from Bob Barney, ge Convervationist, Wallowa-Whitman National Forest, personal mmunication.

Standley Spring and Sturgill Basin

Specific use of the grasslands at Standley Spring and Sturgill Basin is of special interest; the photographic comparisons that follow are of these areas.

The 20-acre reseeding exclosure at Standley Spring was sometimes used to hold sheep, but its primary use after 1911 was as a horse pasture. The Standley Guard Station, built near Standley Spring, was the center of administrative activity in this section of the Wallowa Mountains. It housed the first fire guards who kept several horses available in the pasture during the summer and fall seasons, particularly between 1934 and 1955. In addition, the sheep camp near Standley Spring had a long history as a base camp for camptenders, and their horses and pack strings grazed the grasslands when the sheep bands were in the general area. What the horses didn't take, the sheep did. Records indicate that from 1935 to 1955, when the Standley Lookout was dismantled, there were never less than three horses in the pasture during the summer and many others grazed there periodically. All fences were removed in 1956, but some horses still graze the site each summer. Sheep have grazed there once since 1956.

Recovery: 1955-1976

Sturgill Basin apparently was heavily grazed by sheep for many years after Sampson finished his studies in 1910. A 1912 photo of the reseeded area shows no fence and a patchy cover of grazed vegetation. Sturgill Spring, located near the center of the Basin was also a preferred base camp for herders and camptenders, so use of the Basin by horses and as a sheep bedground most likely resumed and resulted in continued overgrazing. The Basin was closed to sheep grazing in 1941 because of further forage depletion and soil erosion. With the exception of one band of sheep grazing 1 day in 1973, it has remained closed to sheep use.

Both the Standley and Sturgill grasslands have seen, in recent years, an increase in horse use associated with increased recreation use of the Eagle Cap Wilderness, particularly during the fall hunting seasons for upland birds and big game. Standley Spring and Sturgill Spring are popular campsites for elk and deer hunters. For a 2-week period in September, 1975, it was estimated that the grasslands around Standley Spring received the equivalent of 245 days of use by horses from two hunter camps and a Forest Service trail maintenance crew.[9]

Data on use by domestic livestock does not tell the entire grazing history following Sampson's studies. Deer and elk numbers in the Wallowa Mountains have increased greatly over the years.[10] Both deer and elk were extremely scarce in 1900. The deer population increased quickly, and by the mid-thirties there was an estimated 30,000 in Wallowa County. Elk populations were just beginning to expand, but their grazing pressure, particularly on livestock-depleted ranges, was beginning to cause concern. Elk use of forage on a subalpine range in the adjacent Blue Mountains in 1940 was 63 percent of that used by sheep in the same area in 1937 (Pickford and Reid 1943); the area had been closed to sheep grazing in 1938 because of poor soil and vegetation conditions.

Elk numbers have steadily increased since 1940, and deer numbers have fluctuated. There was an estimated 15,000 elk and 40,000 deer in Wallowa County in 1969 (see footnote 10) and 17,800 and 21,600, respectively, in 1979.[11] These game animals graze the Standley and Sturgill grasslands and undoubtedly have had some impact on their recovery.

After examining the Standley Sprir and Sturgill Basin areas in 1955, Sampson stated that the informati on plant succession and its illustr tion through a comparison of photographs would "...provide a contribution to range management that is of real importance, particul since the work dwelt from the star with a range revegetation and management problem."[12] Unfortunately, most of his assessment of plant succession and recovery was not recorded, but his return provid the stimulus for relocating more o his original photographs and recor ing information on plant species.

In describing changes in the follow photographic comparisons, we quo Sampson's description of the initia photograph if it provides informati about the activity or the condition seen. In addition, some description from figure captions in his manuscripts and publications are quoted. Lastly, the conditions in th general area of the photograph are summarized from Sampson's writir or, if easily seen, from the photograph. Data accompanying th repeat photographs are either from plots or transects established in th vegetation shown or from adjacent areas of similar recovery. Maps sh ing the location of the Standley Sp ing and Sturgill Basin areas in the Wallowa Mountains, and the came points for the following photograph are presented in the appendix.

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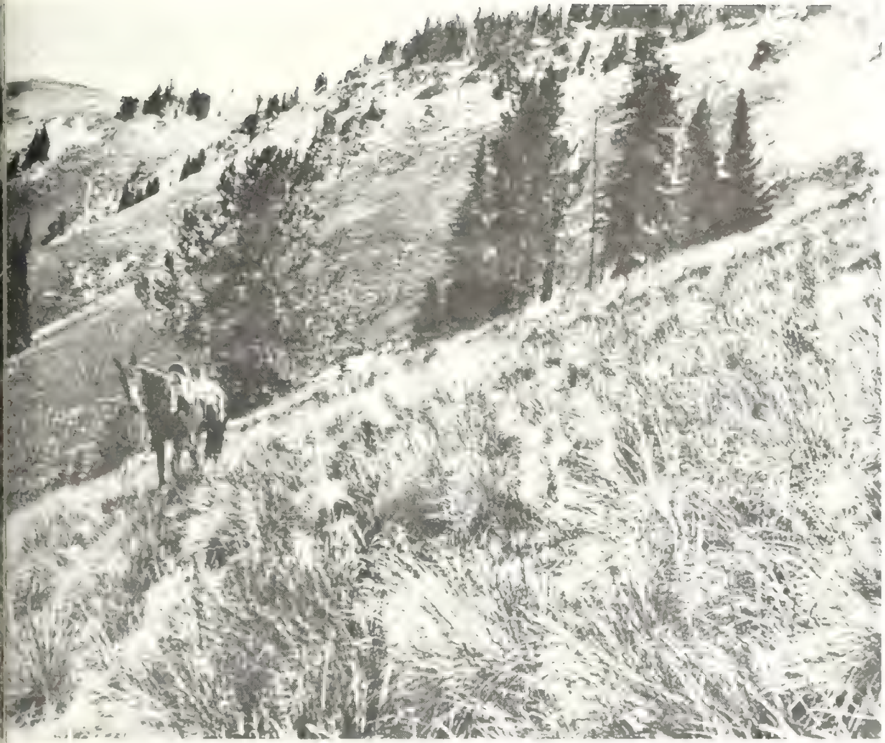
[9] Roy Sines, Ranger, Wallowa-Whitman National Forest (retired). Personal communication, 1975.

[10] Ron Bartels, Oregon State Wildlife Commission. Personal communication, 1970.

[11] Vic Coggins, Oregon State Wildlife Commission. Personal communication, 1979.

[12] Letter to J. Herbert Stone, Regional Forester, Pacific Northwest Region, Fo Service, from A.W. Sampson, March 5, 1955.



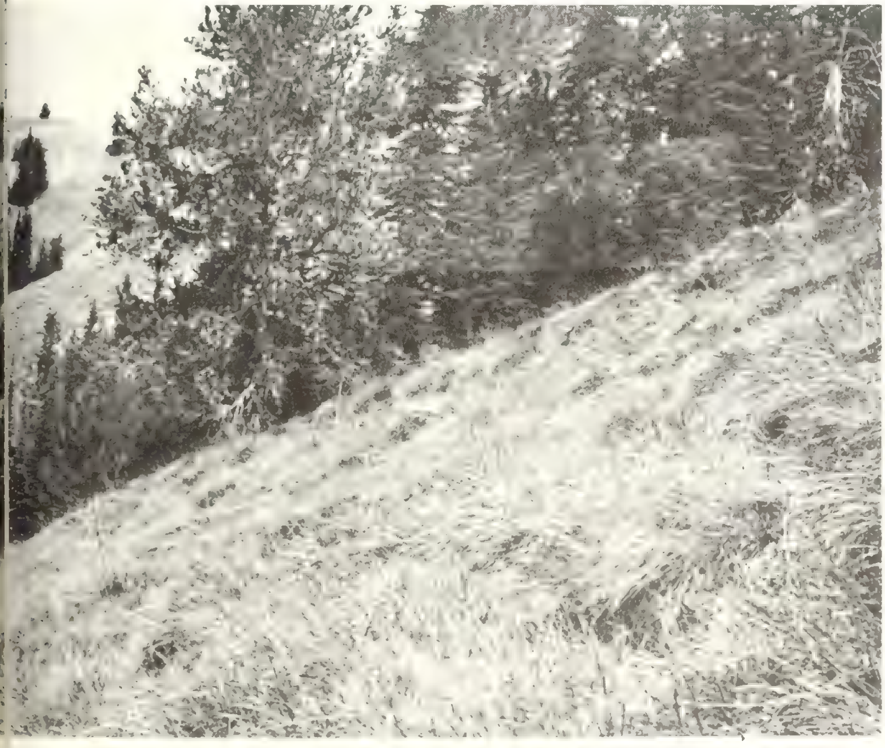


Figure 2. *View north from CP-17, Sturgill Basin.*

Figure 2A. September 1909. *"Wallowa National Forest. Dense stand of green fescue."*

This stand of green fescue probably was the only such community Sampson found on the Standley allotment that approached climax condition. Another 1909 photograph of this site shows the collecting of seed with a comb seed-stripper that would require a vigorous and relatively pure stand of the fescue. The community is in a drainage adjacent to and west of Sturgill Basin. He gathered seed here for studies on germination, establishment, and growth of green fescue seedlings. Except for some spots of barren soil, the middle and background slopes appear to be well-covered with grass.

Figure 2B. August, 1966. *This area, not in the Sturgill Basin area closed to grazing in 1941, had evidence of recent sheep grazing when the photograph was taken. Green fescue was still the dominant species, but other perennials, particularly western needlegrass, were present in the plant community. The sod was slightly terraced or "stepped" and occasionally dissected from active erosion, leaving pedestals or larger hummocks of green fescue sod. Similar stepped sod, but less prominent, shows in the 1909 seed-collecting photo, so apparently no significant erosion had occurred on this site. On the middle and background slopes some portions of the eroded barren soils were more or less revegetated, and, although tree clumps had thickened, tree encroachment into the grasslands was not evident.*

Figure 3. *View north-northeast from CP-1, Standley Spring.*

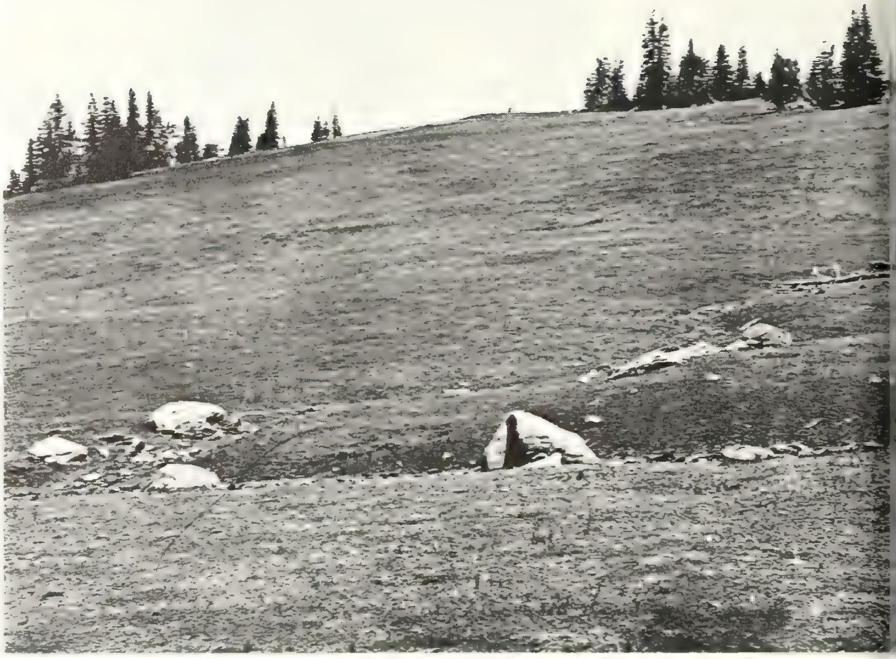
Figure 3A. August, 1907. *"Area denuded through grazing. Summer range denuded of vegetation as a result of competition between sheepmen and cattlemen during the free-for-all grazing period."*

Sampson noted in this general area that Ross sedge, hairstem groundsmoke, Douglas knotweed, and little western needlegrass were the more common species on denuded grasslands and that green fescue existed as widely scattered weakened plants.

In 1955, he recalled that, in 1907, there had been no "feed" left in the lower elevation forested areas beyond the background of this photograph. The ungrazed "timber feed" was luxuriant in 1955, and it was difficult to comprehend that there could ever have been "none."[13]

Figure 3B. August 12, 1955. *Western needlegrass and a sedge (abruptbeak sedge ?) dominated the vegetation. Other species included timber danthonia, bentgrass, spike trisetum, Parry rush (near the timber), Idaho fescue (rocky shallow sites), pokeweed fleeceflower, peregrine fleabane, western yarrow, and littleflower penstemon. Sampson and David Costello, a plant ecologist who accompanied Sampson on the 1955 revisit, concluded the vegetation on the eroded soil would not improve significantly in the future.*[14]

Green fescue, which was sparsely present in the center of the grassland, occurred in good stands on topsoil pedestals around the



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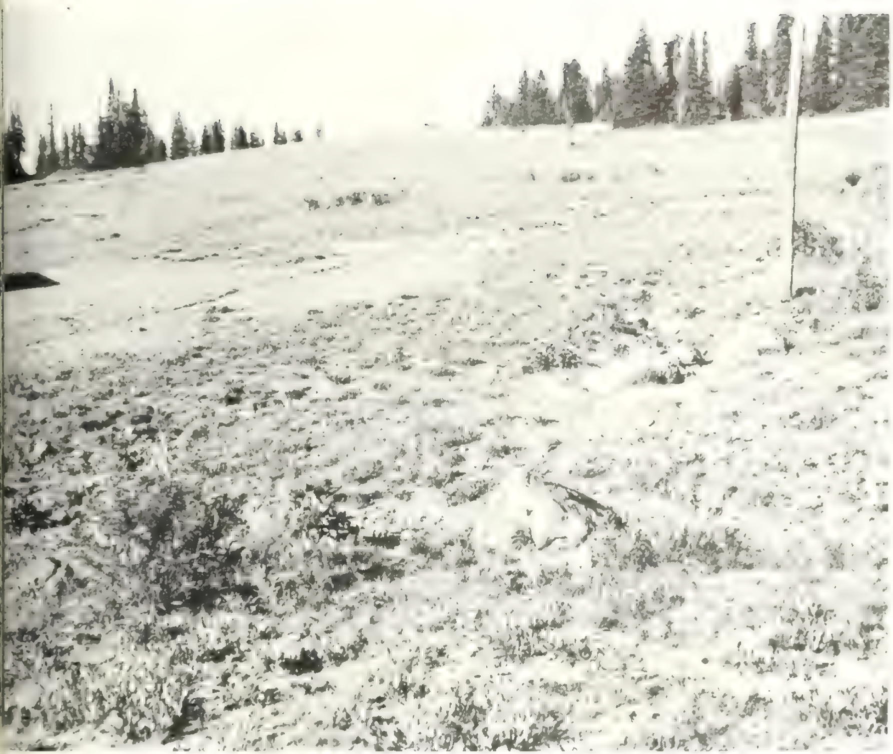
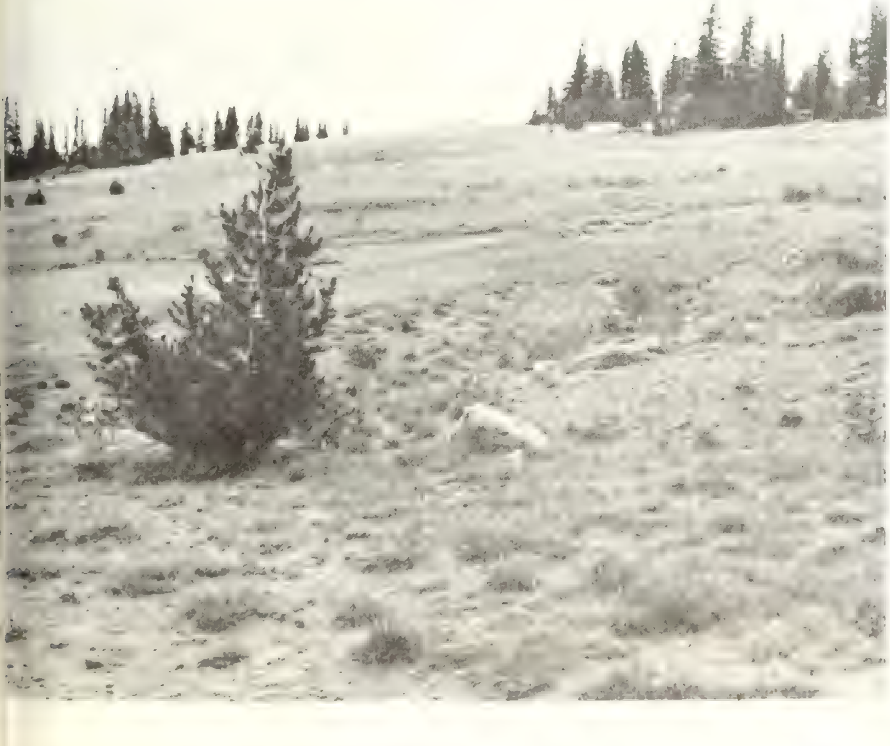
[13] Robert W. Harris. Pacific Northwest Forest and Range Experiment Station (retired). Personal communication.

[14] David F. Costello. Pacific Northwest Forest and Range Experiment Station (retired). Personal communication.





grassland-forest boundary. The presence of the pedestals and the similar surface configuration in both photographs indicated that the topsoil had already been lost from the grassland when the 1907 photograph was taken. Sampson does not specifically mention the existence of soil pedestals, a common, present-day erosion feature of subalpine grasslands, in his publications of the Wallowa Mountain studies or in his photograph captions. We assume, however, from various descriptions, such as "...the original vegetation and network of roots had been seriously injured...by trampling..." (Sampson 1914, p. 113), and "...where many of the tufts had died out, the tussocks were often torn asunder by the sheep passing over them a couple of times" (Sampson 1913c, p. 20), that soil pedestals were present in 1907, but not as prominent as today (see figs. 11-12 and 14-16).

Figure 3C. August 19, 1973. *The needlegrass and various sedges were still dominant in the grassland with the same associated grasses and forbs present. Little western needlegrass and abruptbeak sedge were more abundant in the foreground and drainage area and the forbs less so than observed in 1955, but vegetation cover was less. Western coneflower, apparently not present in 1955, was established in the drainage. Current and future horse use associated with yearly recreational, administrative, and stockmen activities at the nearby Standley Spring campsite and Standley Guard Station will tend to maintain the present plant composition and cover.*

Figure 4. *View east-southeast from CP-2, Standley Spring.*

Figure 4A. June 2, 1908. *"View of the Standley Range with receding snow cover."*

This is the only photograph that shows a major portion (the north half) of the 20-acre exclosure fall-seeded in 1907 to common timothy, Kentucky bluegrass, and redtop. The fence (not yet in place) was across the area in the center of the photograph, up the left margin, and across the skyline. In 1907, the grassland sites seen here were "almost barren" with numerous but inconspicuous annuals and Ross sedge the most abundant perennial. Good vegetative cover occurred only near a few small springs and seeps. In these moist sites, bentgrass, slender hairgrass, alpine timothy, and several sedges and rushes formed dense stands.

The unseeded instrument enclosure, where Sampson followed native species recovery, is outlined by the fence (partially retouched) in and near the receding snow in the upper left (see appendix, fig. 20).

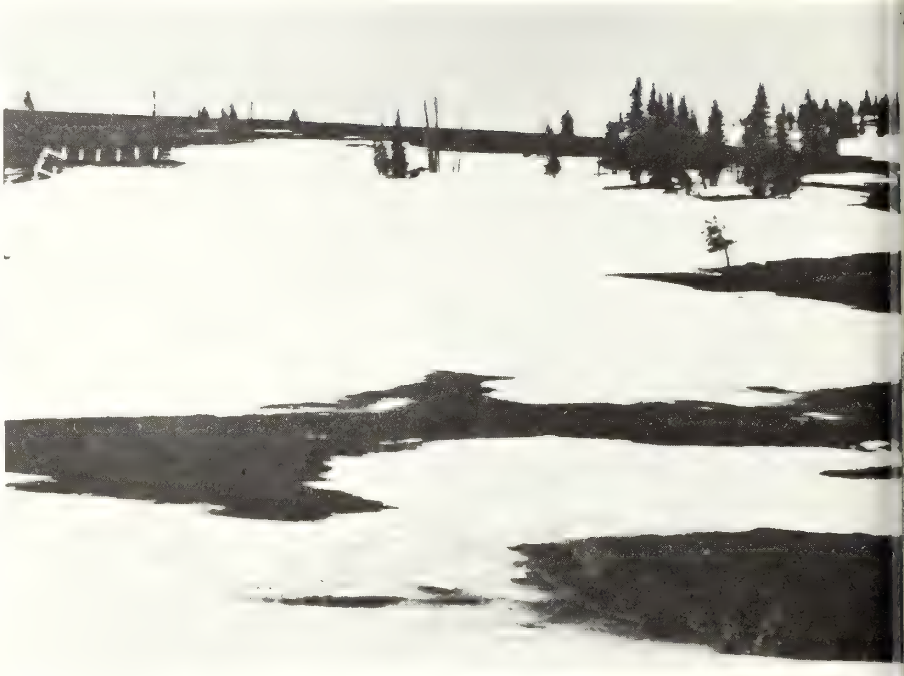
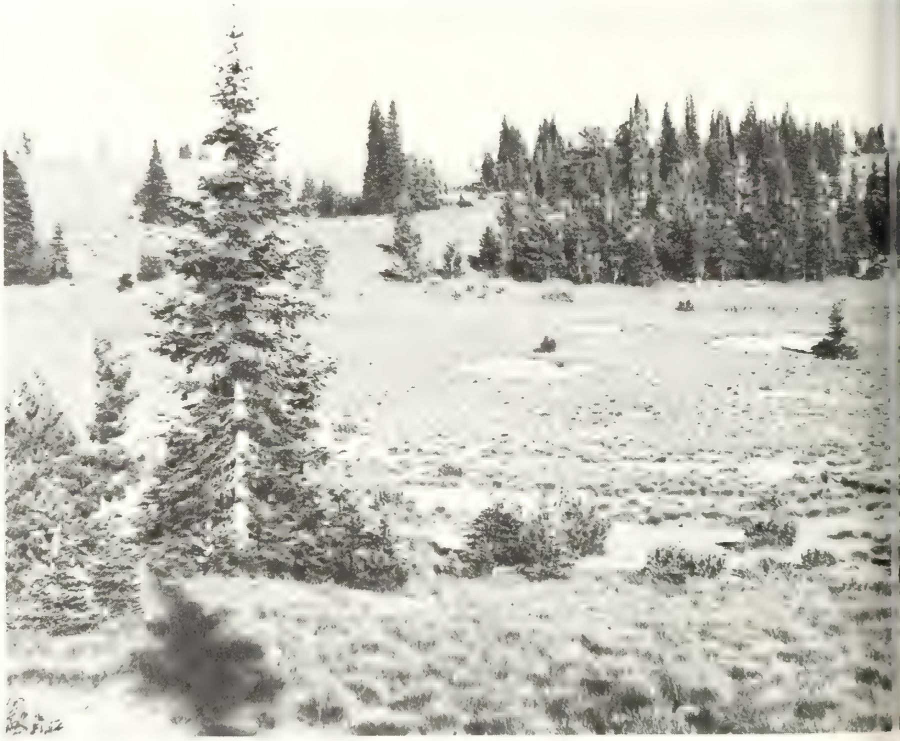


Figure 4B. August 9, 1973. *Parry rush was the dominant plant from the foreground to the circular spots of barren soil. These spots have been maintained in that condition by horses that use them as "rolling beds" and by wind erosion of the fine material. Beyond the spots and the old fence boundary, needlegrass and sedges dominated but yielded dominance to green fescue from the center tree clump to the ridge. No plants of the seeded grasses were found on plots established in the area of the original reseeded exclosure, all or portions of which was used as a holding pasture for sheep and horses until the fence was removed in 1956.*

Vegetative composition and cover varied considerably across the area shown. Average cover of all species was 47 percent, with green fescue accounting for 30 percent. Other important species, in order of cover contribution, were asters, needlegrass, sedges, penstemons, Parry rush, umber pussytoes, and Cusick speedwell.

The most notable change was the establishment, enlargement, and thickening of tree clumps since 1908, a phenomenon more or less evident in many of the repeat photographs.



Sampson estimated that tree clumps occupied 5 percent of the exclosure area in 1907 (Sampson 1913c). Estimates from aerial photographs showed their coverage to be 9 percent in 1959. Counts and aging of stems on grassland plots show subalpine fir, whitebark pine, Engelmann spruce, and lodgepole pine, in order of abundance, had continually spread and become established in the herbaceous communities. Such was particularly evident around the periphery of the enlarged tree clumps and, on this site, primarily after Sampson's 1955 visit. Prior to the closing of the Standley Lookout in 1955, it was common practice for the fire guard to pull young trees to minimize the rate of tree invasion. Tree clumps therefore would have been larger than presently observed had this not been done.

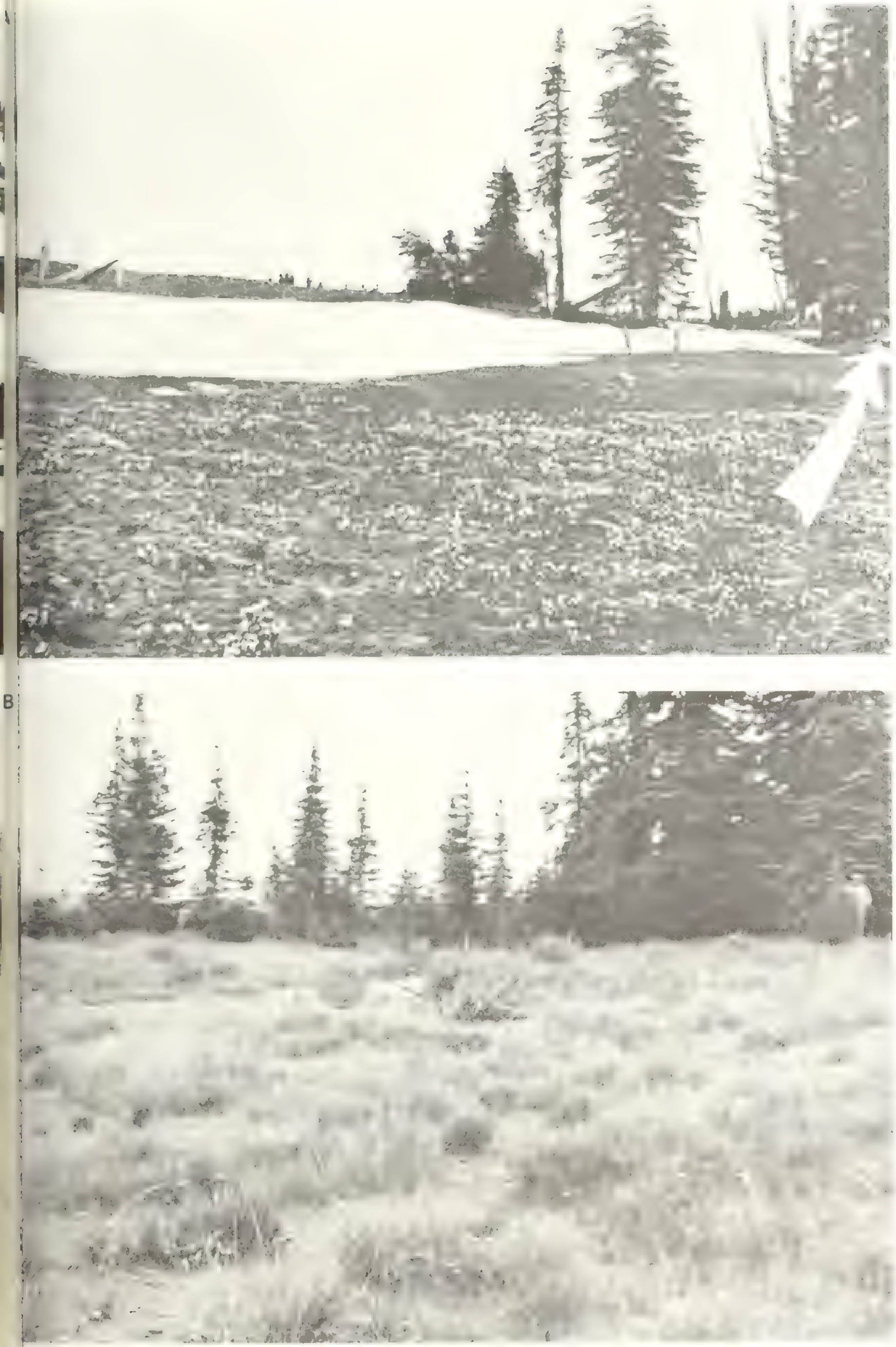


Figure 5. *View southeast from CP-6, Standley Spring.*

Figure 5A. June 29, 1908. *"Same area as #77247. . .[fig. 4, June 2, 1908]. . .showing snow conditions 8 days later. The conspicuous plant in foreground is spring beauty. . . [lanceleaf springbeauty]. . .*Claytonia lanceolata, *which closely follows the recession of snow and announces the early approach of spring."*[15]

Seedlings of the introduced grasses, seeded the previous fall (1907), are not evident in the photograph. Later that summer, however, Sampson recorded an average of 23.4 grass seedlings per square meter (Sampson 1913c). Although this was the lowest count of all his subalpine reseedings, a good cover of grass developed (see fig. 8). The corner of the unseeded instrument enclosure and the clump of subalpine fir, seen here, also appear just left of center near the top of the 1908 photograph in figure 4.

Figure 5B. August 9, 1973. *The dominant plants were green fescue, needlegrass, and sedges. The large plant in the center is pokeweed fleeceflower. No plants of timothy, Kentucky bluegrass, or redtop were found. Subalpine fir had encroached and were still actively encroaching on the late-lying snowbank site. The man is standing on the boulder indicated by the arrow in the 1908 photograph.*

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[15] Either the dates for the 1908 photographs or the "8" days difference Sampson recorded is in error.

Figure 6. *View southwest from CP-4, Standley Spring.*

Figure 6A. October, 1910. *"A hand seeder in use on an overgrazed range area."*

With the exception of some widely dispersed plants on the slopes in the background, this site was without vegetative cover. This photograph and those in figures 7 and 8, were taken to illustrate Sampson's methods of spreading and covering grass seed in his experimental plots. The barren sites illustrated not only straddled a main access trail but also were adjacent to the permanent sheep camp at Standley Spring. The constant trailing and, most likely, long use of the area as a bedground had eliminated the vegetation. There is no record of this area having been seeded.

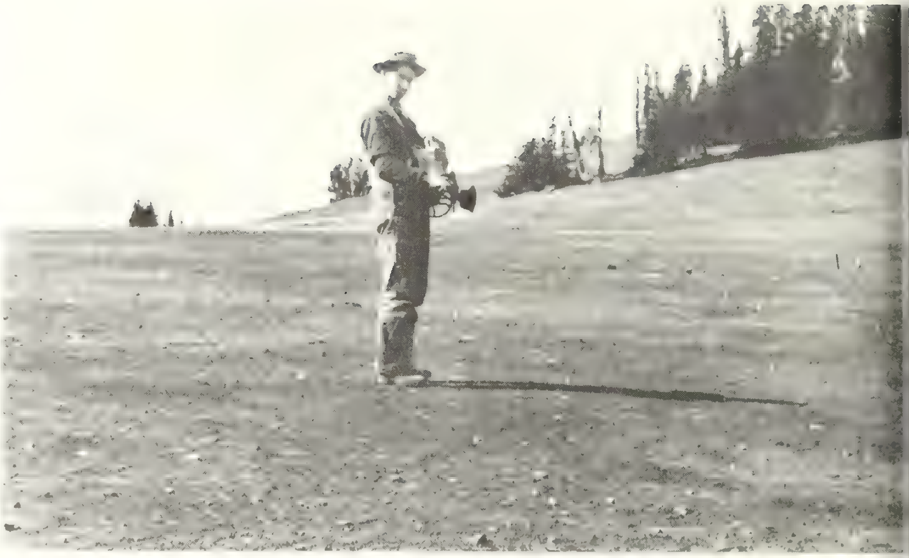


Figure 6B. August 9, 1973. *Perennial forbs dominated the 15-percent vegetative cover. In order of abundance, littleflower penstemon, leafybract aster, umbellate pussypaws, umber pussytoes, and western yarrow accounted for 70 percent of the cover; needlegrass, sedges, and Parry rush 28 percent; and green fescue 2 percent. An almost pure community of Parry rush occurred on the background slopes. Parry rush is not readily grazed by sheep, so possibly the plant was present in 1910. In Sampson's ordered listing of the 44 plants supplying 90 percent of the sheep forage, Parry rush was rated 42 (Sampson 1914).*

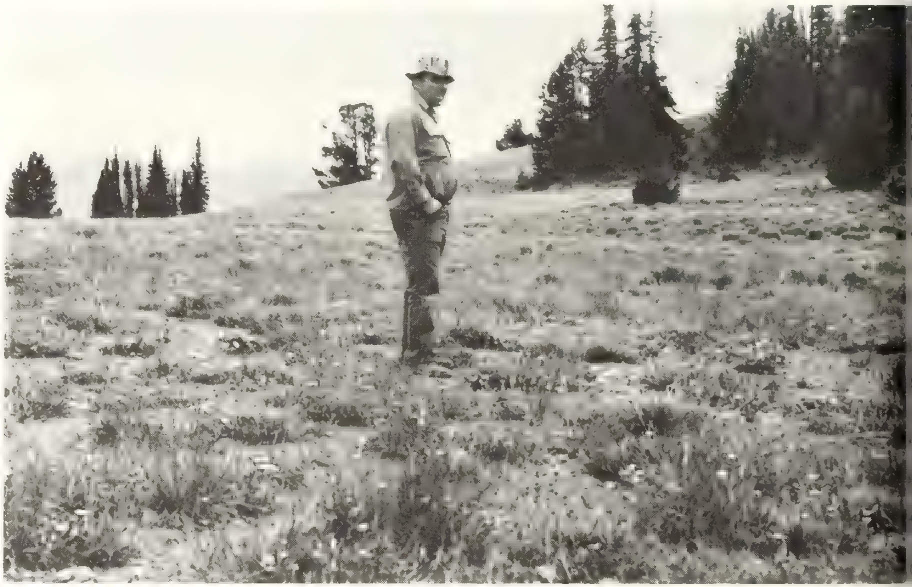


Figure 7. *View north from CP-5, Standley Spring.*

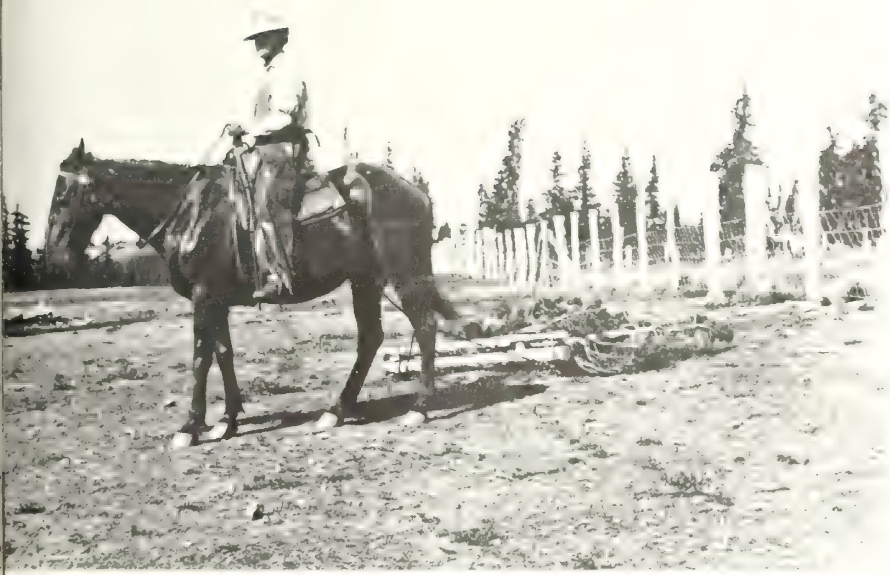


Figure 7A. September 15, 1909. *"A brush harrow in use." It was constructed ". . . with the materials available. . . [in]. . . about one hour's time."*

A few unknown perennial plants were present on this barren site which is part of that described for figure 6. The good grass cover to the right of the fence is the ungrazed, 2d-year growth of timothy, Kentucky bluegrass, and redtop seeded in the fall of 1907. Sampson stated that timothy had become dominant and redtop, although present, was not adapted to the site.

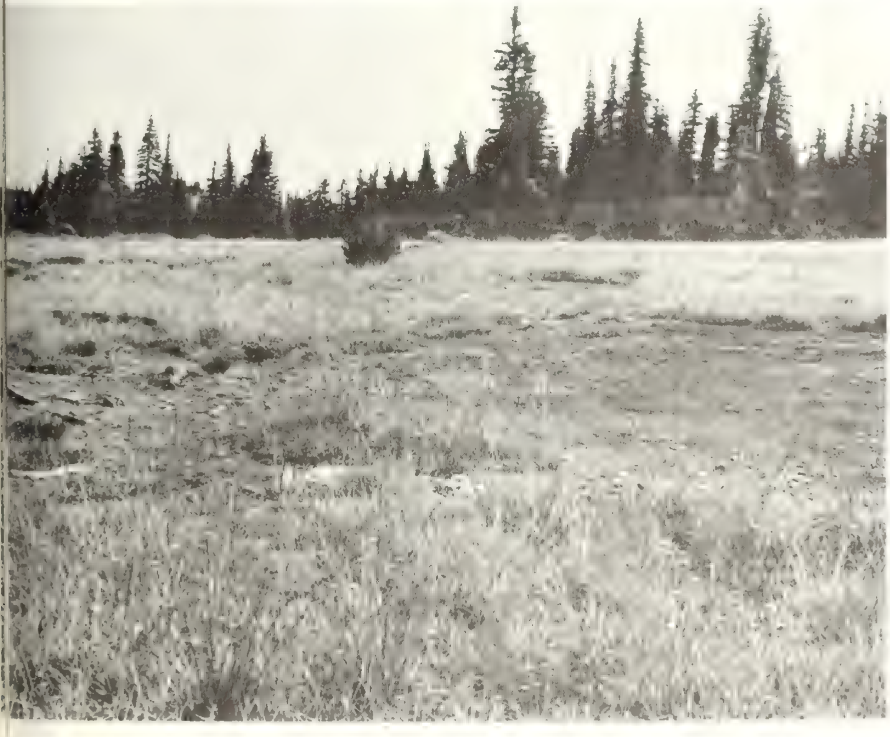


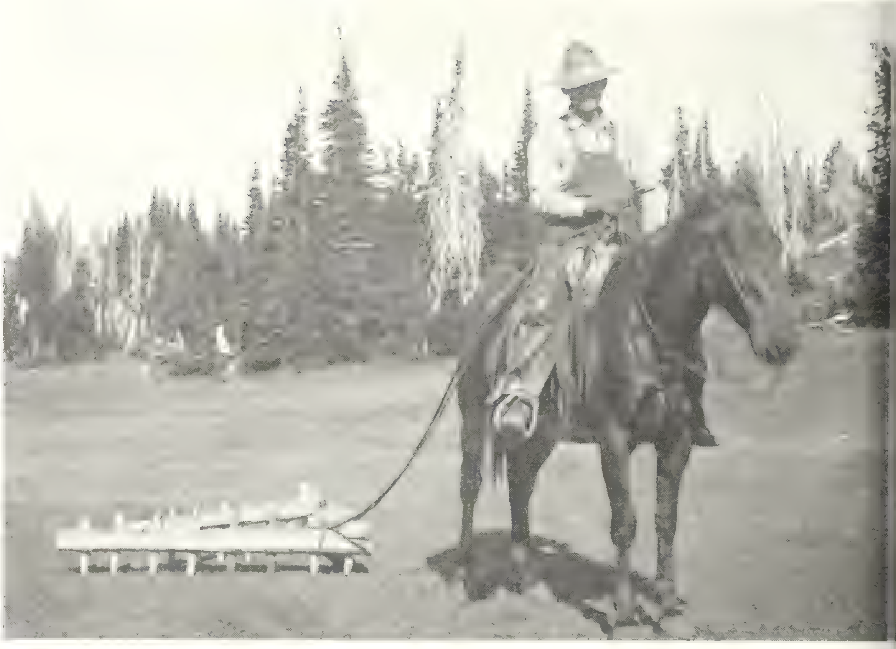
Figure 7B. August 9, 1973. *Vegetative cover and composition was dominated by needlegrasses and sedges. Leafybract aster, littleflower penstemon, and spike trisetum were the more common associates. Scattered seedlings and many small plants of little western needlegrass, spike trisetum, and umbellate pussypaws were noted on the spots of bare soil. It was also noted that horses, however, in using these "rolling beds," tended to eliminate any plants and pulverize the soil. Wind erosion of soil out of these spots was observed.*

Figure 8. *View northeast from CP-3, Standley Spring.*

Figure 8A. September 15, 1909. *"A wooden A-harrow recommended for use on well-packed soils where the brush harrow is not effective." It was "...used effectively in an artificial reseeding near timberline, Wallowa National Forest, Oregon."*

The site appears to have been completely denuded of vegetation.

Figure 8B. August 9, 1973. *Vegetative cover was sparse with much barren soil still present. Forbs, such as western yarrow, littleflower penstemon, leafybract aster, pussytoes, and cinquefoil were prominent. Needlegrasses, sedges, and Parry rush accounted for only 20 percent of the total plant cover. Vigorous green fescue plants occurred in the background around young subalpine fir and whitebark pine. These trees are established in former grassland. The large plant in the foreground is pokeweed fleeceflower, a long-lived forb commonly found on depleted subalpine grasslands. Because of its proximity to Standley Spring and the main access trail, this site was still receiving heavy grazing and trampling by pack and recreational horses.*



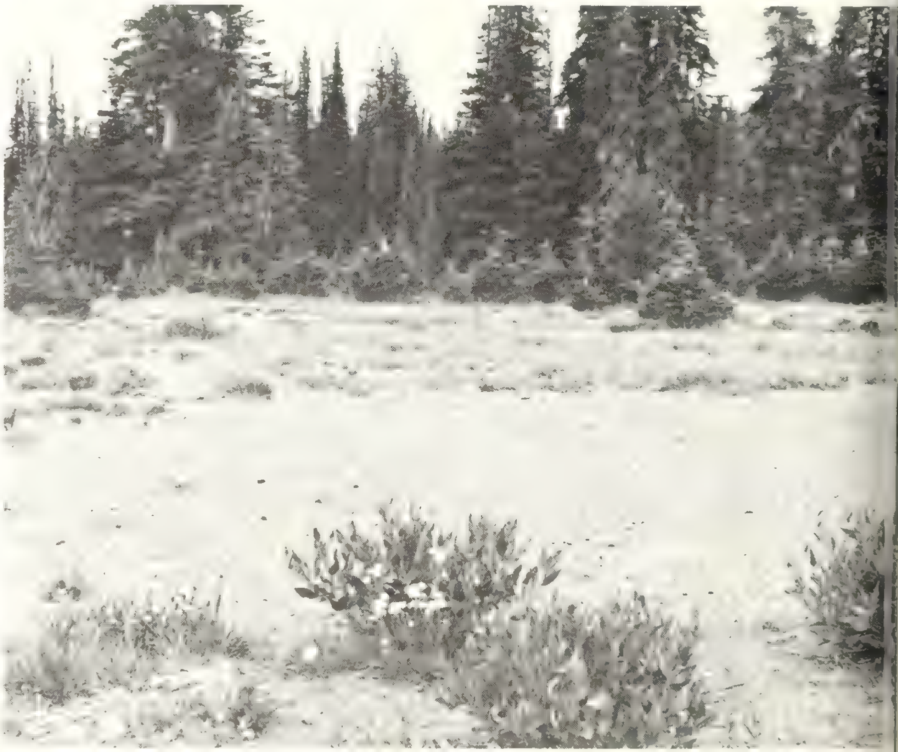
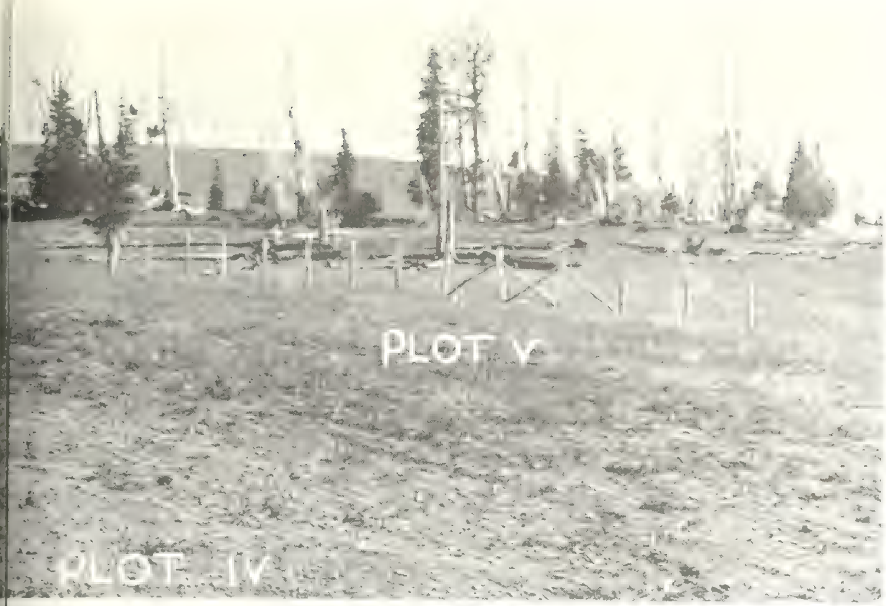


Figure 9. *View east from CP-13, Sturgill Basin.*

Figure 9A. September 24, 1908. *"View of the seeded area...[in Sturgill Basin]...at the end of the first year of growth. The young growth is mainly timothy. On plot V the seed was brushed in while plot IV was 'harrowed' by trampling sheep."*

The best seedling stand (92.8 seedlings/m²) was on the brushed area V; however, this density and that on the trampled plot IV (38.5/m²) is not readily apparent in the photograph (Sampson 1913c).

Sampson selected and reseeded this 5-acre bedground in the fall of 1907 to replicate the 20-acre reseeding at



Standley. He stated that "... the ground is smooth except for occasional narrow ruts caused by erosion in the spring. The area formerly bore a heavy growth of green fescue but is now bare of vegetation save for a few scattered tufts of yarrow,... sedge, and needlegrass" (Sampson 1913c, p.12). Judging from this photograph and that in figure 10, this was surely true for most of the area, but he noted on his map (Sampson 1913c, p. 12) that a thin stand of green fescue and needlegrass occurred in his plot I, an area not seen in this photograph.

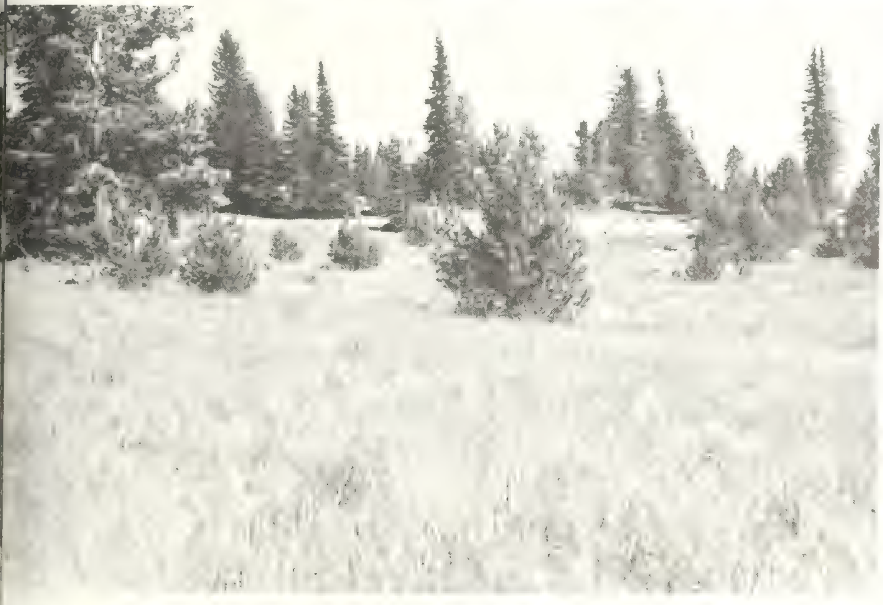


Figure 9B. August 13, 1955. *In the immediate foreground, an almost pure stand of western needlegrass (90 percent of the species composition) accounted for most of the 22-percent vegetative cover. Other species listed were sedges, umber pussytoes, umbellate pussypaws, Parry rush, orange agoseris, Douglas knotweed, and spike trisetum. Step-point transect data showed that 48 percent of the still-smooth ground surface was covered by dense grass litter. A small erosion channel runs parallel to and near the position of the old fence and was likely a result of both sheep trailing along the fence during the study years and from water erosion thereafter.*

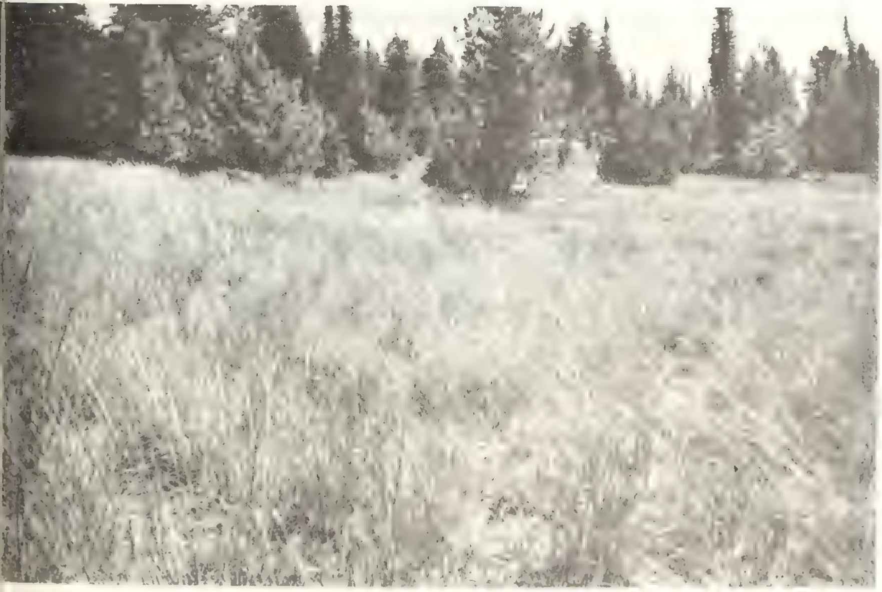


Figure 9C. August 8, 1973. *Species composition and coverage in the foreground was similar to that measured in 1955; however, data from plots distributed within the grass community (to the far tree clumps) showed that needlegrass, sedge, and green fescue equally accounted for two-thirds of a 39-percent vegetative cover. Of the remaining 18 species listed, cover of both Parry rush and umber pussytoes was 3 percent.*

As at Standley, subalpine fir and whitebark pine had densely reestablished in the old tree clump area circumscribed by the snags in the 1907 photograph. Their seedlings also had become established, many since 1955, in the sparse grassland in the middle distance. But tree invasion of the 1907 seeded exclosure area was almost nil at this date.

Figure 10. *View west from CP-14, Sturgill Basin.*

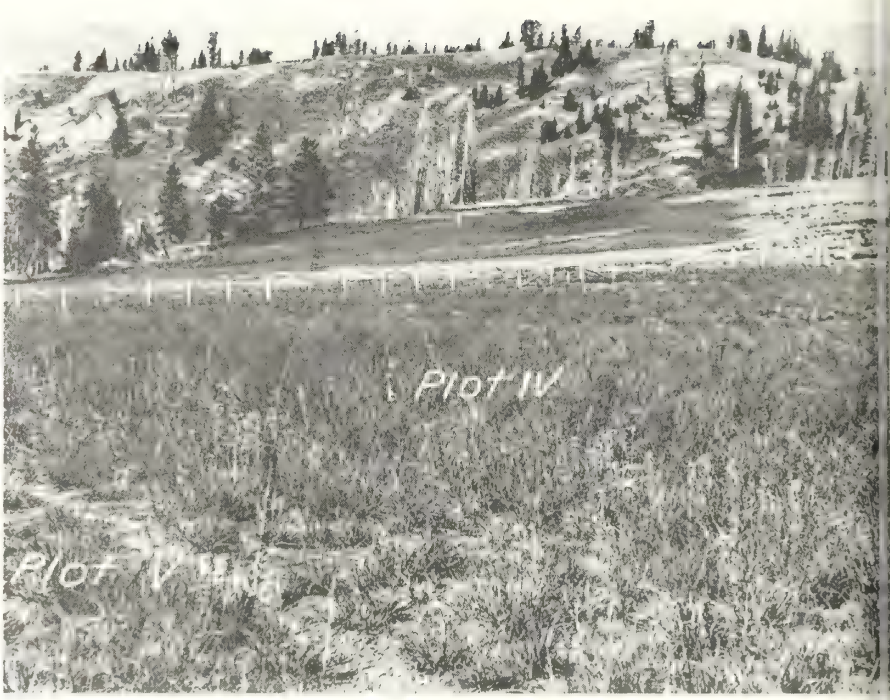
Figure 10A. July, 1909. *"Another view of plots IV and V. . . [in the Sturgill exclosure]. . . showing the forage growth at the end of the second year. The brushed (V) and trampled (IV) areas have a ground cover of approximately 60 and 40 percent, respectively. Species predominating at this time is timothy."*

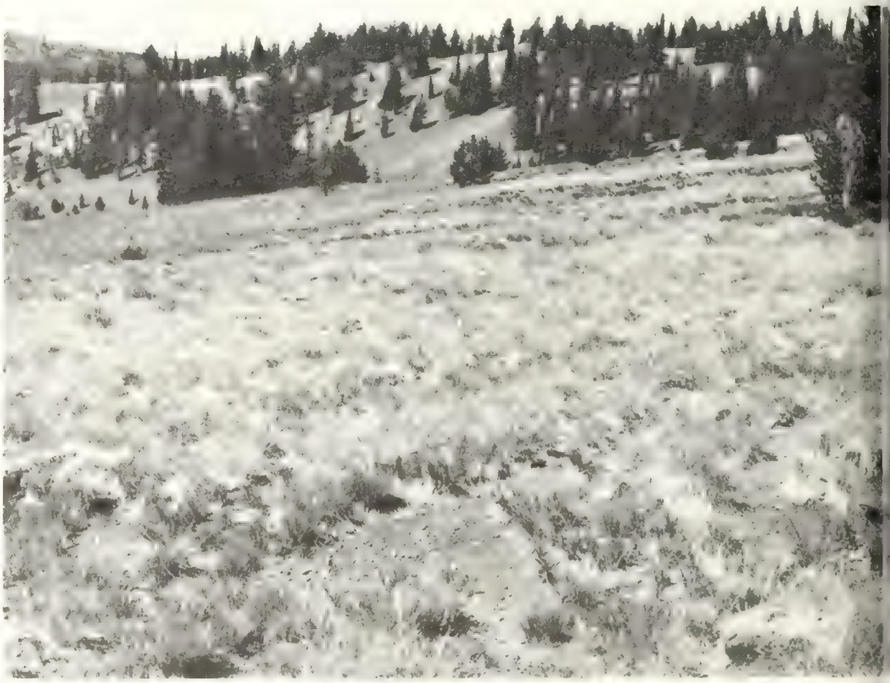
Other than the seeded species, western yarrow is recognizable and relatively abundant. The dark and light areas beyond the fence are deeply eroded soils, barren of vegetation.

In the publication of his results (Sampson 1913c), an error was made, either in the map of the exclosure (his fig. 3), the seedling data (his table 3), or in the labeling of this photograph and that in figure 9. From the positions established for rephotography, the labeling on this photograph has been corrected to correspond with his original map, but the error in his table 3 still exists.

Figure 10B. August 8, 1973. *Transect data and photos in 1955, 1962, and 1966 showed that plant cover was similar to that observed at this date. Where vegetation existed, the estimated cover (59 percent) was primarily needlegrass (16 percent), green fescue (16), sedges (12), and umber pussytoes (10). All trees established in the grassland were whitebark pine.*

In 1955, one of us (Hall) noted that vegetation in Sturgill Basin was still recovering from the poor condition observed prior to its closure to grazing in 1941. Needleleaf sandwort mats still persisted as relics, sedges and western needlegrass were invading barren soils and gullies, and vigorous green fescue plants were becoming established in the needlegrass and sedge dominated communities on the old "brushed" plot. In 1973, the large barren soil areas within and beyond the former fence boundary remained relatively devoid of plants (see fig. 11) indicating that the invasion noted in 1955 did not continue on these areas. Attempts between 1940 and 1963 to revegetate these sites by reseeding introduced species with various mulching and fertilizer treatments were unsuccessful. A transplanting trial by one of us (Hall) in 1964, using





mature green fescue plants, was completely successful; the plants were still present in 1977. This substantiates Sampson's observations that soil drought and spring and fall frost heaving on barren soils can eliminate a seedling crop, but not damage older plants.

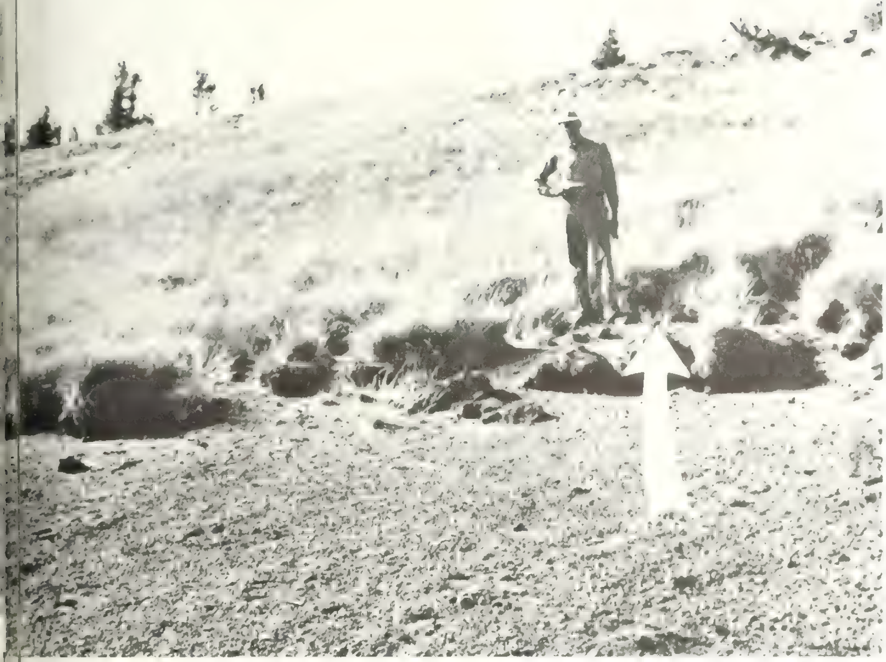


Figure 11. *View north from CP-15, Sturgill Basin.*

Figure 11A. August 13, 1955. *Photographed during Sampson's 1955 trip, this site lies outside of but adjacent to Sampson's plot I in the Sturgill exclosure. It was on part of this plot that he obtained a poor stand of timothy because the "superabundance" of native plants ". . . prevented much of the seed from coming in contact with the soil" (Sampson 1913c, p.12). No notes were taken in 1955 on which species dominated the dense grass community.*

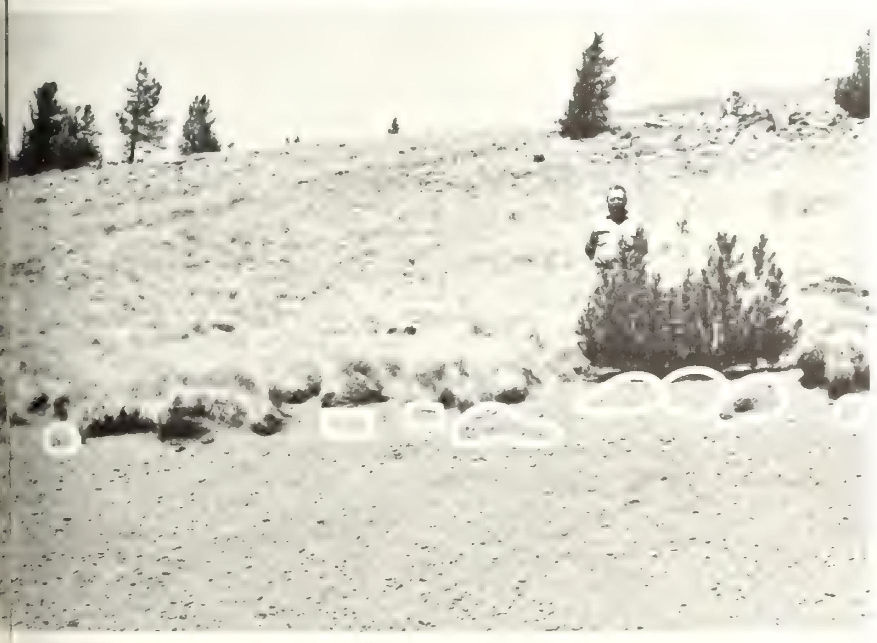


Figure 11B. August 8, 1973. *Vigorous green fescue on large soil pedestals, up to 12 inches in height, dominated the grassland community as it most likely did in 1955. Umber pussytoes, sedge species, and western needlegrass also occurred in all plots but totally accounted for only a small percentage of the 56-percent cover. A few small plants of one species, umbellate pussypaws, were established on the barren soils.*

The soil pedestals, supporting vigorous green fescue in 1955, were still present whereas those with less vigorous plants or devoid of vegetation in 1955 (outlined on photo B) are not. This comparison shows the stability of the soil pedestals when bound by dense live roots of fescue and their instability without this live root mass. Although bound tightly by dead roots, the pedestals eventually erode from water, wind, and frost action, a process that is speeded up when the pedestals are subject to trampling (Sampson 1913c). If quickly revegetated by grasses, sedges, or some forbs, however, the pedestals have been known to maintain their structure for more than 40 years, even under moderate sheep use (Reid et al. 1980). Tree invasion and establishment does not insure continued sod stability; an erosion pavement was characteristic under the few trees established in the pedestaled grasslands in Sturgill Basin. In this photograph, the whitebark pine, present as a seedling in 1955 (arrow), had become established on eroded soil between remnant pedestals.

Figure 12. *View north from CP-9, Standley Spring.*

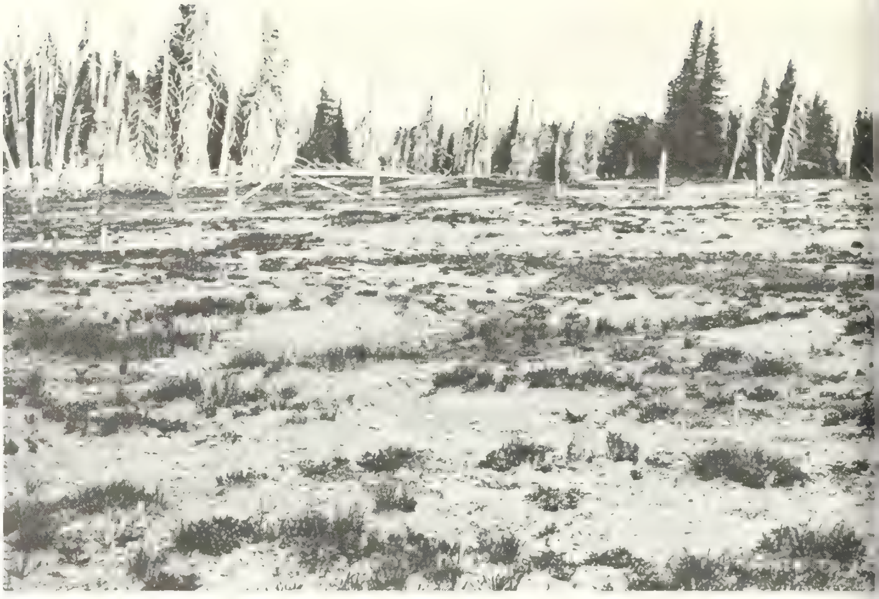


Figure 12A. July 12, 1907. *"View of Station No. 4. . .[instrument enclosure]. . .looking north. A small badly depleted area. . .[to be]. . .protected by the Forest Service against grazing for five years. . .to determine the time . . .[required]. . .for revegetation which is usually slow on badly trampled lands. . . . "*

The photograph shows the general vegetative cover in the instrument enclosure at Standley the year it was fenced. The records from a permanent quadrat (see fig. 15), seen near the left margin in this photo, provide the only quantitative data available and indicates that most of the plants seen are green fescue, fernleaf licoriceroot, and Cusick speedwell.

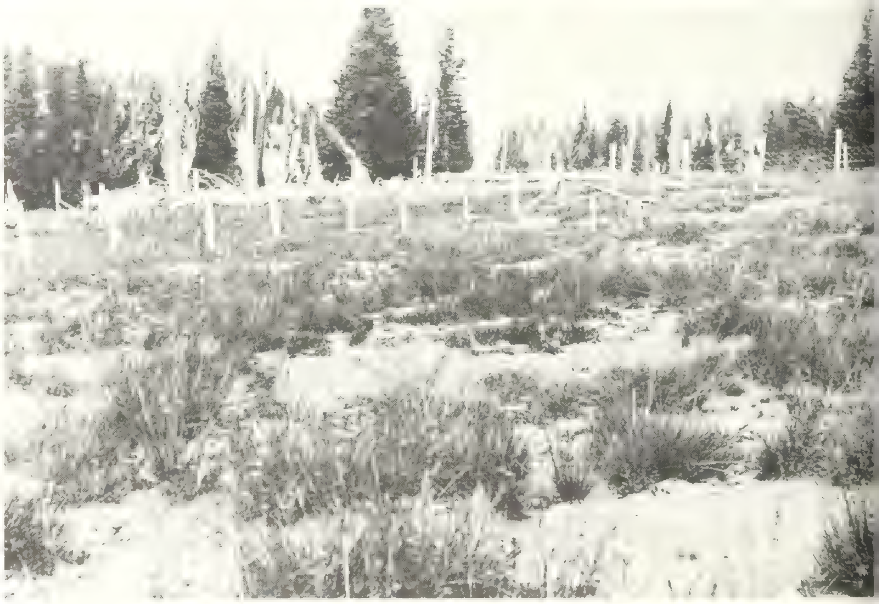


Figure 12B. July 15, 1909. *"The increase in forage is due to vegetative growth and not to reproduction from seed."*

Sampson provided no quantitative description of the plant species or cover seen in this photograph nor in the following 1911 photograph. After 3 years of protection from grazing, however, he noted vigor of all plants had improved and some had increased in size, but few perennial grass seedlings had become established on the barren soil areas. Green fescue, needlegrass (coarse bunches), fernleaf licoriceroot, and Cusick speedwell appear in the photograph.

Note the absence of most alpine fir snags present in the 1907 photo. They were felled to supply fence post material for the Standley exclosure which was completed in the spring of 1908.

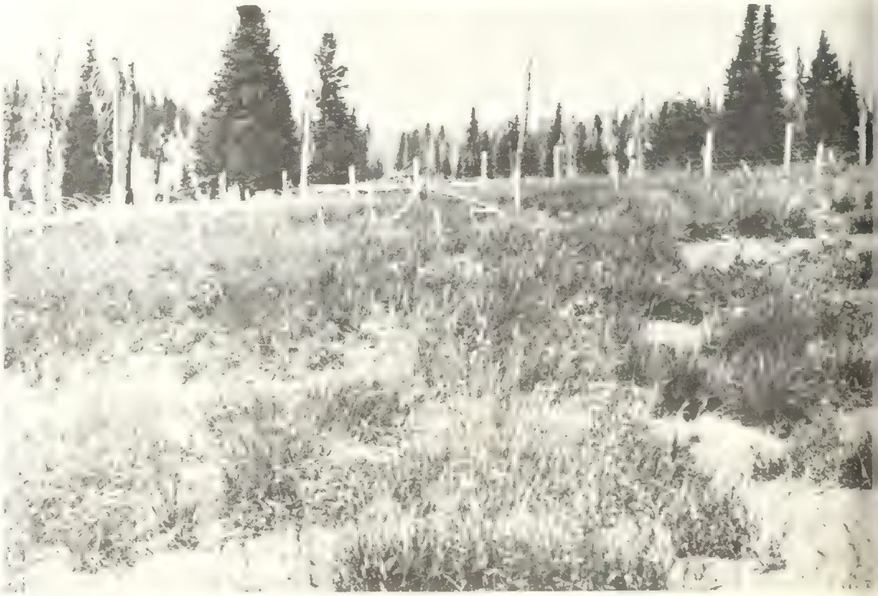


Figure 12C. 1911. *After 5 years of protection, Sampson wrote that vigorous green fescue was now producing an abundance of viable seed, and new fescue plants were established in the open spaces between older plants.*

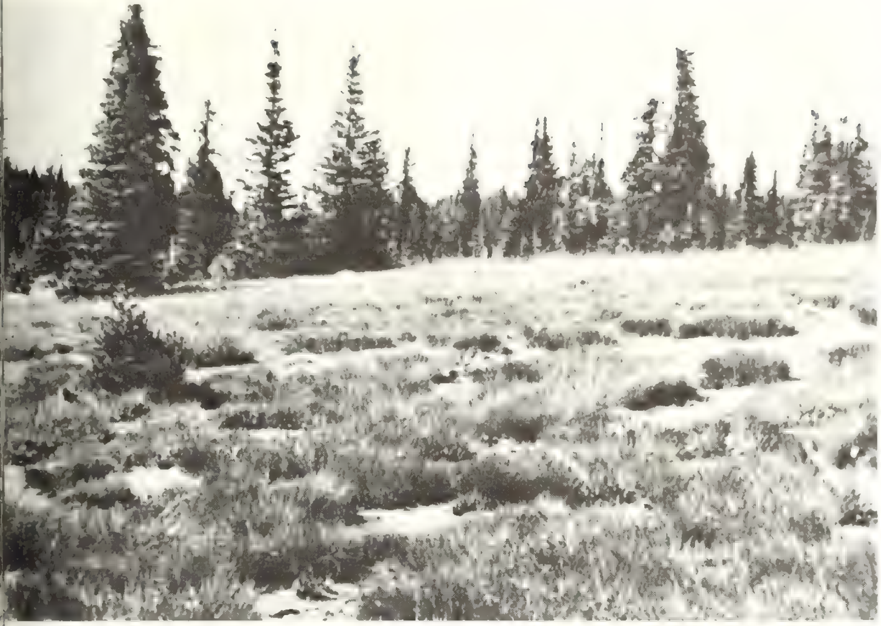


Figure 12D. August 12, 1955. *Vegetative cover was 32 percent, of which three-fourths was green fescue. Fescue plants were almost wholly confined to elevated pedestals or larger hummocks of soil. Most of the remaining cover, in order of abundance, was needlegrass, leafybract aster, and Cusick speedwell. Transect measurements in 1964, following a 4-year drought, showed that cover had decreased to 25 percent. Most of the decrease had been in green fescue. Needlegrass and sedge cover had not changed.*

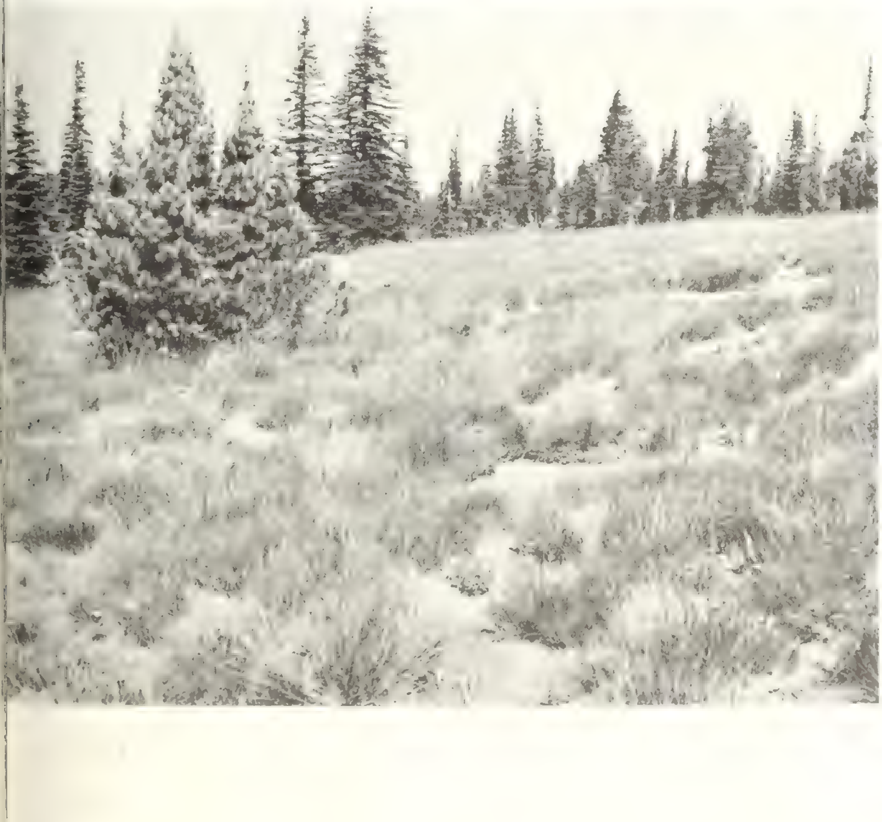


Figure 12E. July 29, 1976. *Vegetative cover (measured in 1973) was similar to that measured in 1955. Green fescue again comprised three-fourths of the cover. Leafybract aster, needlegrass, and abruptbeak sedge accounted for most of the remainder. Several seedlings of whitebark pine and subalpine fir are established in the area shown. The 12-ft whitebark pine was about 3 ft in 1955.*

Figure 13. *Arthur W. Sampson holding copper tag found at Standley Spring in 1955. The tag is inscribed "Plot I Sept. 16, 1907 Denuded."*

Table 3—Percent of cover on charted quadrat on Standley allotment 1955, 1964, and 1972

Species	Percent plant cover 1955	 1964	 1972
green fescue	27.6	18.4	27.2
abruptbeak sedge	1.3	4.7	6.5
leafybract aster	7.9	1.2	1.9
Cusick speedwell	1.1	.9	.9
haircap moss	*	.7	1.4
peregrine fleabane	1.1	*	*
slender hairgrass			*
umbellate pussypaws	*	*	*
whitebark pine (seedling)			*
Total	39.0	25.9	37.9

* = Less than 0.5 percent.

The cycling of green fescue cover observed in this photograph series between 1955 and 1976 was also observed on a chart quadrat established in 1955 near CP-10 (for location, see appendix, fig. 20). It was at this camera point that Sampson, in 1955, found the copper tag, still wired to a small fragment of wood, that he used to mark his denuded quadrat #1 in 1907 (fig. 13). Plant cover (table 3) was charted in 1955 and recharted in 1964 and 1972 (fig. 14).

In 1955, green fescue occupied a major portion of an elevated soil hummock oriented vertically through the center of the quadrat. Leafybract aster occurred in dense small mats on the periphery of the fescue sod. Abruptbeak sedge, third in importance, occurred in two clumps, one on the hummock and the other on the eroded soil. Cusick speedwell and peregrine fleabane were most prominent on the eroded soil.

From 1960 through 1963, particularly in 1963, precipitation during the growing season in northeastern Oregon was below average and temperatures were generally above average. Beginning in 1964, with the exception of a very dry season in 1967, precipitation and temperature were generally normal; but precipitation was much above average in 1970, 1971, and 1972.[16]

Following the dry period, green fescue cover had decreased and retreated to the periphery of the hummock in 1964. Its tiller density was sparse and vigor was poor. The sodded area in the center of the hummock appeared as dead plant crowns, tillers, and litter. Abruptbeak sedge and haircap moss cover had increased, the sedge from establishment and growth of new plants on the soil hummock and the haircap moss from enlargement of the original mat. Aster, speedwell, and fleabane had decreased in cover, mostly from a decrease in size or a breaking-down of former clumps and mats to many individual plants. Most of these small individual plants were established near the periphery of the elevated hummock or on the eroded soil around its base; few plants, of a species, occurred in the center of the hummock or on the eroded interspaces between hummocks (hummocks in the general area were spaced 1-3 ft apart). To a lesser extent, new sedge plants also tend to have a greater affinity for establishment in the hummock edges.

Dense vigorous green fescue tillers again occupied much of the hummock area in 1972, and its cover about equaled that charted in 19 The sedge plants had thickened to definitive clumps, and the mat of haircap moss had doubled in size. Large leafy plants of speedwell and aster resulted in similar or slightly increased cover, although their plant numbers had decreased. As in 1955 these forb and sedge plants occurred primarily near the edge of the elevated hummock and/or the edge of the live fescue sod. This site association has been noted in other similarly eroded, subalpine communities (Ellison 1949, Maser and Strickler 1978). Ellison's experiments and observations showed that plant establishment, resulting in such associations, occurred because soil moisture and stability was better and temperature extremes and frost heaving less common on and around the base of the sodded hummocks than on the eroded interspaces. His work supports Sampson's earlier observations on the inability of most native plants to become established on the eroded soil and that continued grazing was not solely responsible in preventing establishment.

Figure 14. *Charts of permanent quadrat on Standley allotment, 1955, 1964, and 1972.*

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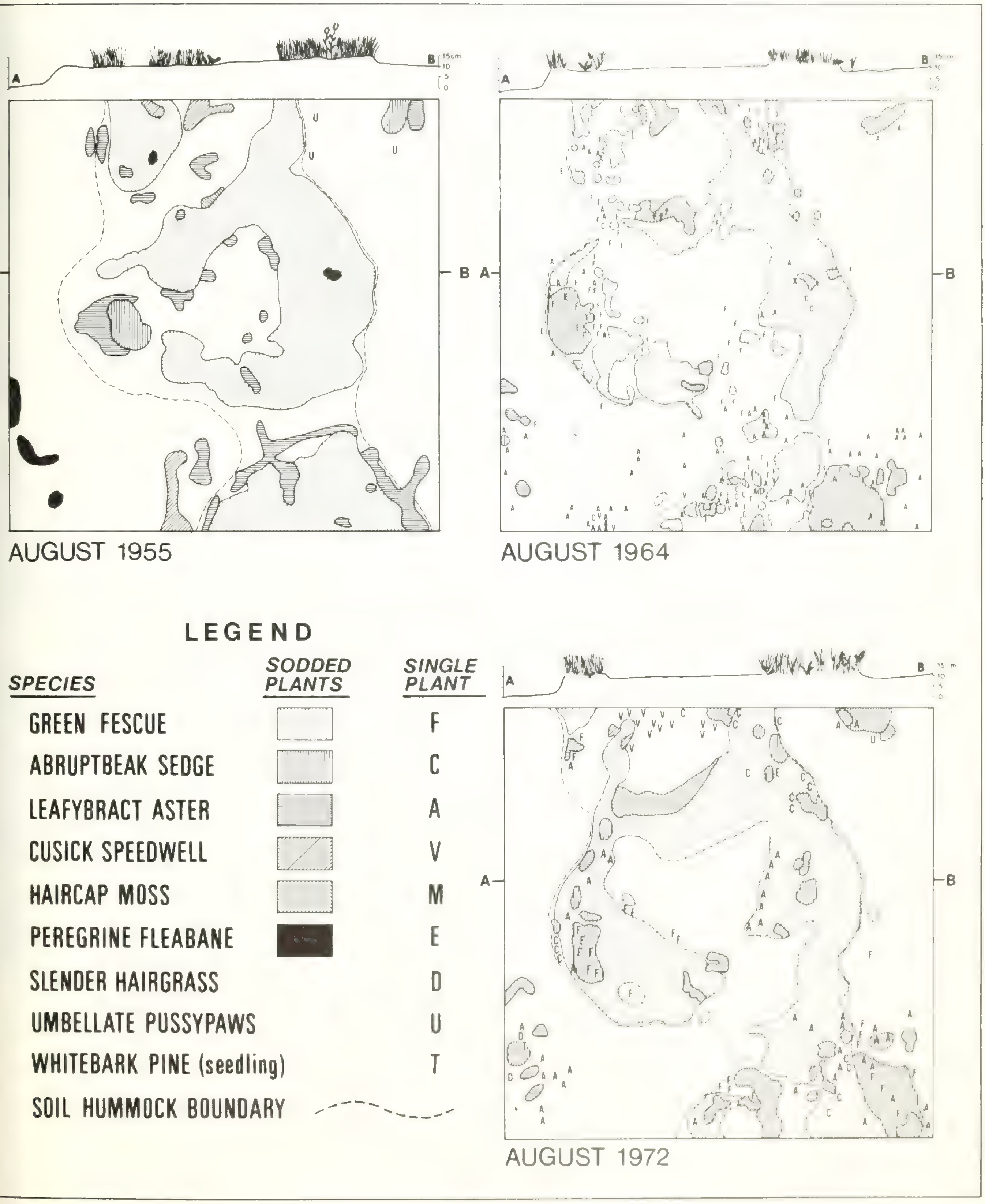
[16] Annual summaries, climatological data, Oregon. From National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Asheville, North Carolina.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AUGUST 1955
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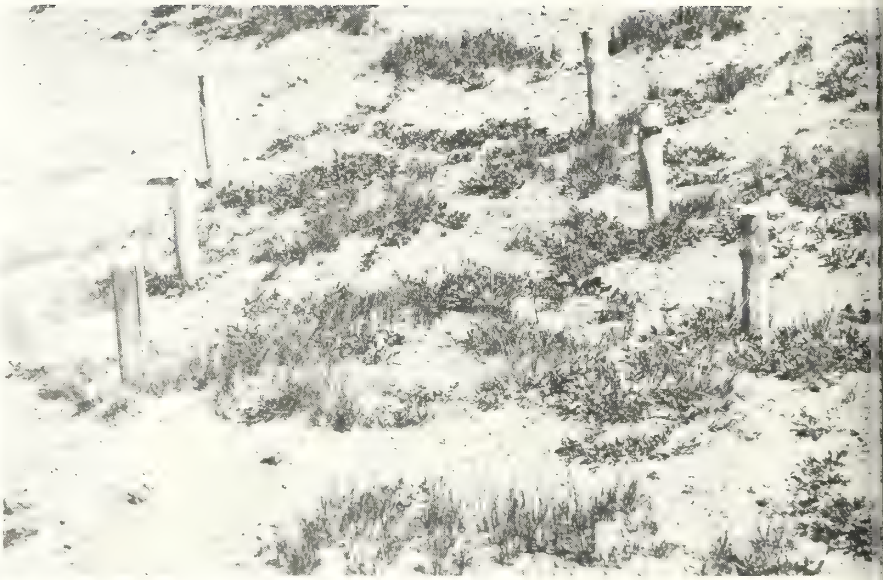
LEGEND
SPECIES
SODDED PLANTS
SINGLE PLANT
GREEN FESCUE F
ABRUPTBEAK SEDGE C
LEAFYBRACT ASTER A
CUSICK SPEEDWELL V
HAIRCAP MOSS M
PEREGRINE FLEABANE E
SLENDER HAIRGRASS D
UMBELLATE PUSSYPAWS U
WHITEBARK PINE (seedling) T
SOIL HUMMOCK BOUNDARY

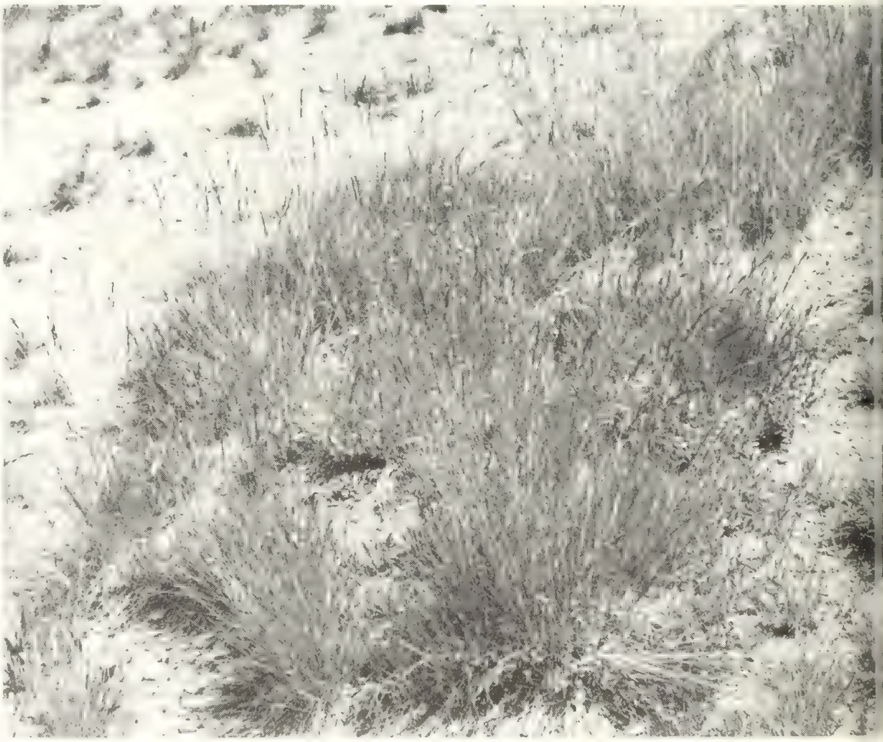
Figure 15. *View northeast from CP-7, Standley Spring.*

Figure 15A. August 16, 1907. *"Detailed photo of quadrat at Station 4."*

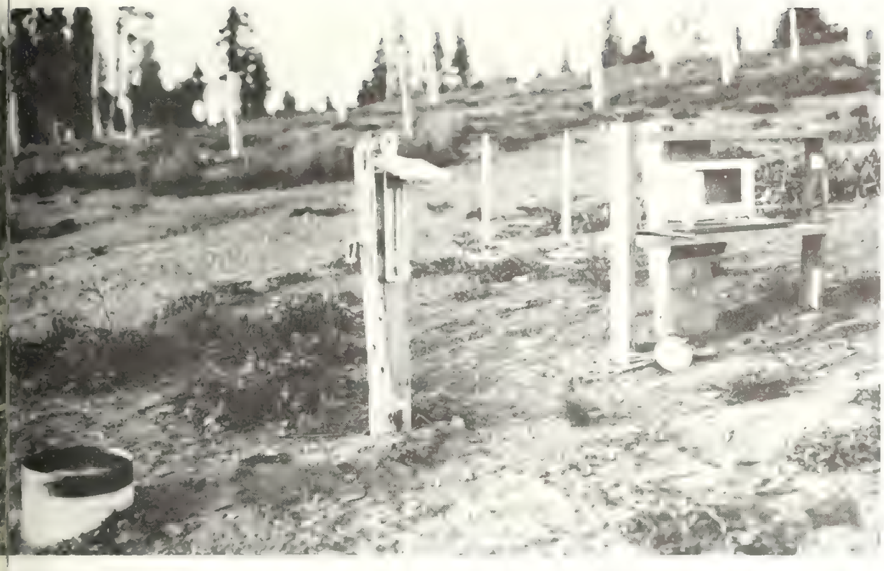


Sampson did not record the number of the quadrat shown, but the distribution of vegetation on the quadrat somewhat matches that which he charted 43 days earlier on his permanent quadrat #1 (Sampson 1914, p.122). Total vegetative cover was 15 percent, of which fernleaf licoriceroot and green fescue accounted for 8 and 5 percent, respectively. The remaining cover consisted of Cusick speedwell, littleflower penstemon, and abundant but inconspicuous Douglas knotweed plants. Recharted in 1909, Sampson noted that slight increases in plant size of licoriceroot and green fescue had increased the cover to 18 percent and that five seedlings of green fescue had survived the summer drought (Sampson 1914).

Figure 15B. July 29, 1976. *Green fescue dominated the plot area and occurred on soil pedestals elevated 3-6 in above the surrounding surface. Western needlegrass and Cusick speedwell also occurred on the plot. Leafybract aster and sedges were absent on the plot area but common in adjacent vegetation.*



Soil pedestals, a common phenomena in eroded subalpine grasslands, were prominent along both sides of the swale oriented diagonally across the photograph and just beyond the plot. The 1907 photograph shows a relatively uniform soil surface with only slight erosion in the swale area. Thus, in 1976, assuming that the tops of the pedestals were at the level of the old surface, considerable soil erosion continued after Sampson's studies, but when this occurred and at what rate, is unknown. Slight soil erosion was still occurring in the poorly vegetated swale and between the elevated pedestals.



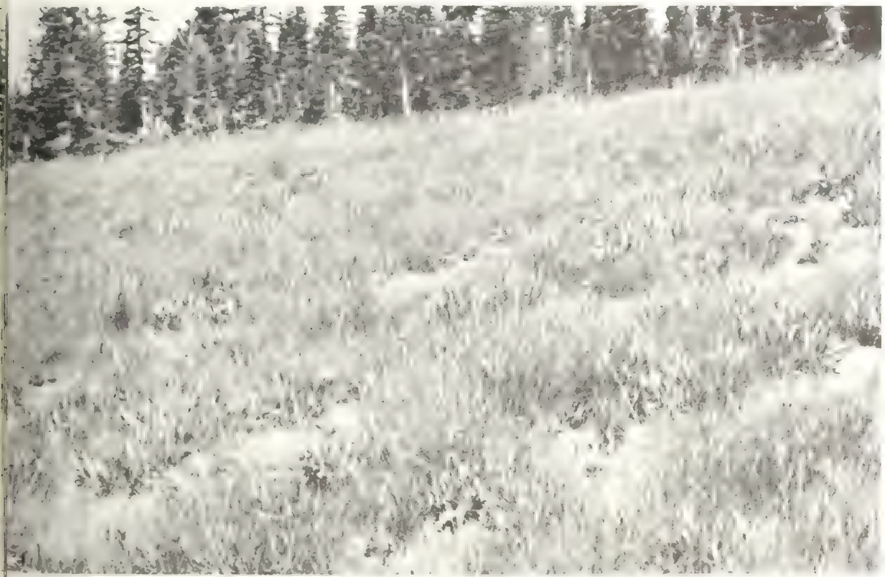


Figure 16. *View north-northeast from CP-8, Standley Spring.*

Figure 16A. July 1909. *Sampson recorded summer precipitation, evaporation, air temperature, humidity, and soil moisture at this installation. After 2 years of protection, the majority of plants around the installation are fernleaf licoriceroot, a prominent species in the enclosure in 1907.*

Figure 16B. July 29, 1976. *The estimated 50-percent vegetative cover consisted of green fescue (25 percent), leafybract aster (15), needlegrasses, sedges, and Cusick speedwell (8). The licoriceroot was found neither here nor at any other site within the fescue community but was noted elsewhere on relatively barren, shallow stony soils. As noted in figure 15 and shown here, most green fescue growth was confined to soil pedestals and hummocks, indicating further erosion of the land surface had occurred after 1909.*

Figure 17. *View northwest from CP-11, Standley Spring.*

Figure 17A. August 16, 1907. *"The overgrazing by sheep. A depleted sheep range in the Wallowa Mountains. . . [at 7,400]. . . feet elevation in the Hudzonian zone, showing the upper limits at which seeding will pay. Note the characteristic scattered, but luxuriant growth of whitebark pine and subalpine fir. At slightly higher points where these trees become dwarfed, reseeding will not pay."*

The few plants seen (species not recorded) appear to be forbs. Plant cover appears to be denser toward the larger group of sheep in the middle distance, beyond which was the "almost barren" soils of the Standley exclosure, seeded about 1 month after the photo was taken.

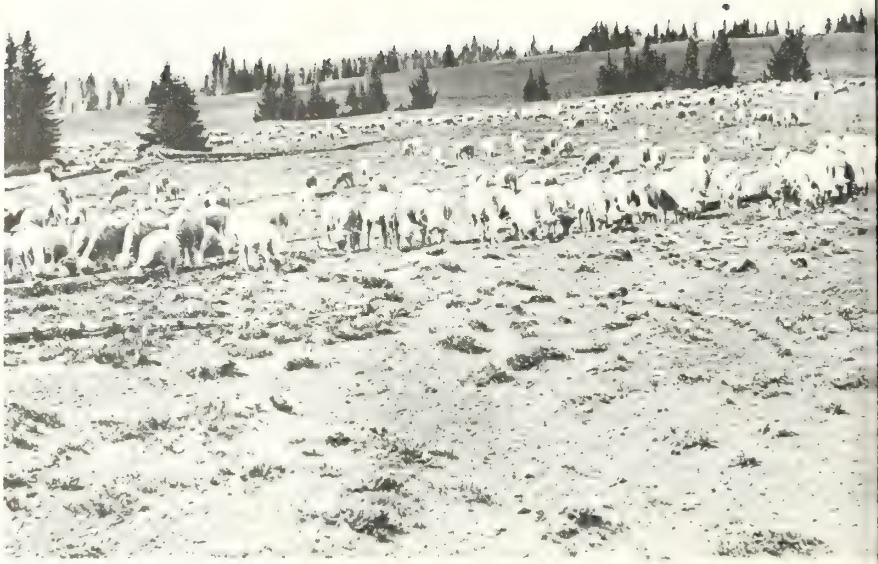
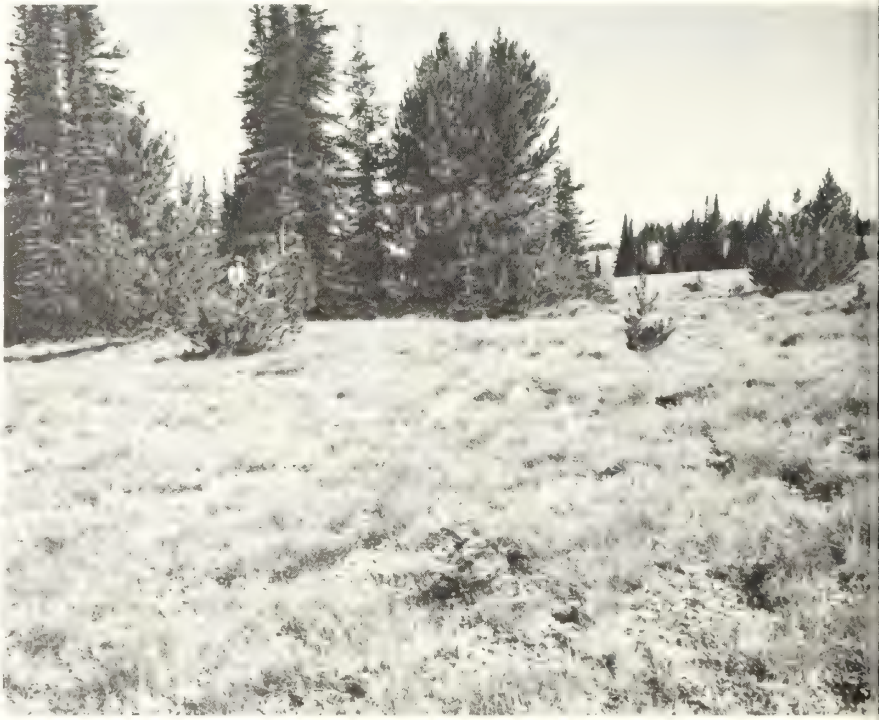
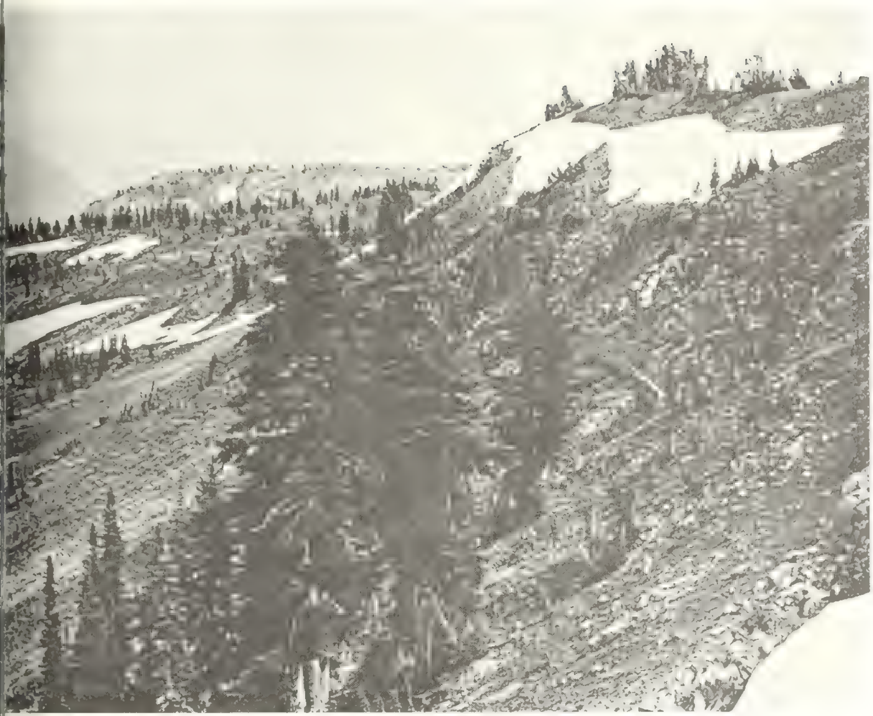


Figure 17B. August 9, 1973. *Thirty-one herbaceous species accounted for the vegetative cover (60 percent) in the foreground plant community. Woolly and umber pussytoes, Parry rush, green fescue, and sedges equally accounted for 44-percent cover, and the needlegrasses, Cusick speedwell, and timber danthonia, 12 percent. Parry rush and umber pussytoes (the low white plant) were the dominant species in the foreground and the green fescue in the grassland beyond the trees.*

The taller subalpine fir trees are those seen in the 1907 photograph. The whitebark pine (center) is 53 years old. Considerable expansion of subalpine fir and whitebark pine seedlings into grassland communities had occurred in this area since 1955, particularly north and northwest of the tree clumps where snow lies late and shade delays summer soil drought.





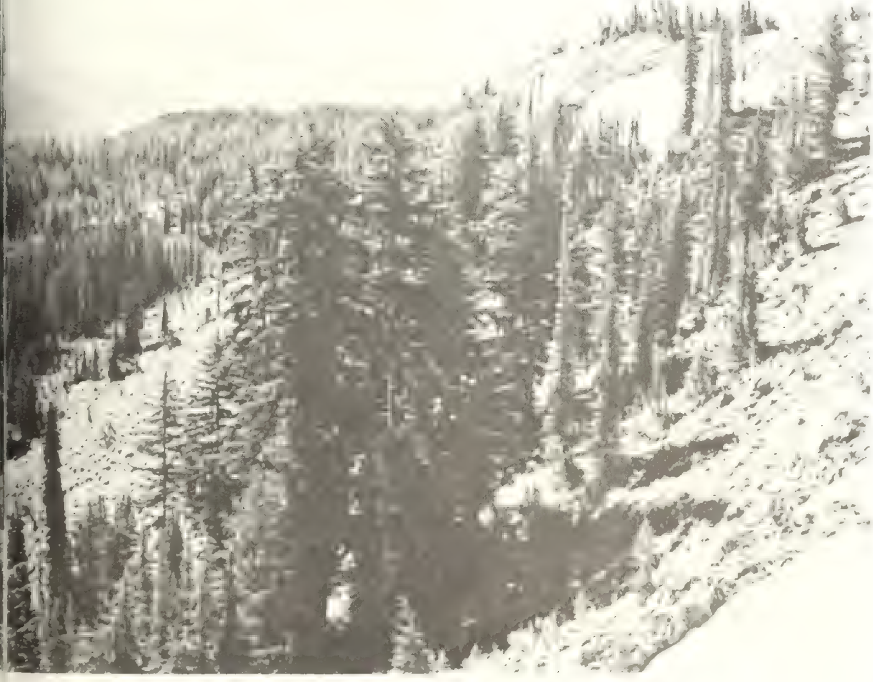


Figure 18. *View southeast from CP-12, Standley Spring.*

Figure 18A. July 25, 1908. *"View of Bear Creek drainage from ridge east of old. . .[Standley]. . .Guard Station showing the dominantly irregular topography of the upper grazing lands."*

The stony steep slopes in the right foreground are almost devoid of plants; some pokeweed fleeceflower is evident in the photograph. The grassland slope in the left middleground is badly trailed. On the middle distant ridge are a large number of fallen snags. Sampson noted that, about 20 years previous, practically all of the timber in a large portion of Bear Creek had been killed by a fire and had left the ground strewn with logs (Sampson 1913c).

Figure 18B. July 28, 1976. *Whitebark pine and subalpine fir density had greatly increased on the middle distant ridge, although many were probably present as seedlings and saplings in 1907. Only small remnants, particularly root pieces, of the fallen snags were present. Mountain hemlock (center foreground), Engelmann spruce, and subalpine fir groupings had enlarged, and many young trees were becoming established on the still actively eroding soil around the enlarged tree groups. Herbaceous vegetation cover was still sparse and California falsehellebore, pokeweed fleeceflower, nettleleaf gianthyssop, and penstemons were the more conspicuous of the several forbs present. Green fecsue occurred on the hummocks in the left middleground.*

Notable is the similar size of snowbanks in both photographs. The 1975-76 winter produced above average snowpacks in the Wallowa Mountains, and good moisture conditions prevailed through the 1976 growing season (Soil Conservation Service 1976). Sampson (1909, p. 21) indicated that similar snowpacks had occurred in 1908; ". . . little of the ground on the main high range was free of snow until July 1, and even then portions of the largest snow drifts remained."

Discussion

Sampson's work, between 1907 and 1911 in the Wallowa Mountains, was significant in subsequent management of National Forest ranges. The management recommendations he developed on the depleted Wallowa ranges were put into practice, albeit slowly not only in the Wallowa Mountains but also elsewhere, and were generally adopted into range management thinking in the Western United States. Today, deferred grazing, in some form, is used on many National Forest allotments either to improve poor range conditions or to maintain good conditions through improved livestock distribution.

Sampson's reseeding guidelines, based on the Wallowa work, are often reiterated in reseeding research and rehabilitation of disturbed sites (for example, see Brown et al. 1976). His published recommendations, such as for preparing a seedbed, seeding species adaptable to the site and environmental conditions, seeding in late fall prior to snowfall, covering the seed, and protecting the seedlings from grazing through the first growing season, are still valid for high elevation lands.

The 1955-1976 photographs, of the same areas photographed by Sampson between 1907 and 1911, illustrate the "remarkable recovery" which Sampson often spoke of during his 1955 visit. The early vegetation depletion and soil erosion, however, had essentially modified the grassland habitats, regulating the rate and amount of recovery of species and plant communities, so that no areas recovered to green fescue climax. The present vegetation is a variety of species in a number of plant communities in secondary successional stages.

Where uneroded topsoil remained or occurred in sufficient amounts in remnant pedestals, green fescue has either regained or shares dominance, particularly with needlegrasses and sedges, and vegetative cover ranges between 40 and 60 percent.

On eroded sites, which often had no vegetation in 1907, recovery has been variable. Those seeded by Sampson now have a native plant cover that is 20-50 percent less than that which recovered naturally from remnant fescue. The reseeded grasses are not present today, but we believe the reseeding survived for a sufficient time to provide an environment suitable for speedier reestablishment of native species, a phenomenon recently noted by Brown et al. (1976) in Montana. Green fescue is the major component of communities where it was present when reseeded and subsequent erosion was not severe. Needlegrasses, sedges, and forbs often dominate reseeded areas where topsoil was lost and fescue was absent in 1907, but green fescue has reestablished in these areas, and in some, is codominant with these species.

Some barren sites, not seeded in 1907, essentially remain in that condition. Some are near trails and campsites, and indications are that continued grazing, particularly by horses, is a major deterrent to recovery. On other sites, seeding and transplant trials indicate that spring frost heave and summer drought are still effectively preventing seedling establishment even though the sites have had long protection from livestock use.

Some sites, barren in 1907, exhibited a fair to good vegetation cover after 1955. Needlegrasses, Parry rush, sedges, and numerous forbs, several of which are long-lived, dominated these sites. The cover is generally between 20 and 40 percent, and green fescue has only recently begun to increase its cover in the plant community.

It appeared that maximum vegetative cover and plant density potential on many eroded sites had been reached before 1955. Further improvement between 1955 and 1976 was minimal, but in the future, green fescue can be expected to slowly reestablish itself on most sites (Reid et al. 1980). Where these grasslands occur along access trails adjacent to and within the Eagle Cap Wilderness, recovery may be slowed because of the selective heavy grazing of green fescue by horses. Observed heavy use of green fescue by elk in other subalpine areas show they too could slow recovery. If needs for forage and protective plant cover in subalpine areas increase over that now supplied by the recovering plant communities, more intensive management or manipulation of the land, vegetation, human use, and grazing animals will be necessary.

If the need is great in limited areas, it may be necessary to proceed with the agricultural approach and develop man-directed communities as Sampson did. If so, adaptable native or commercially available species must be seeded and perhaps enhanced by fertilization, weeding, or other agronomic techniques. Where frost heaving is intense, transplanting may be necessary. Costs will be high and subsequent management must be intensive. Ecological trends, such as the recent widespread encroachment of trees into grassland communities, may have to be controlled.

If needs are simple and static, then naturally occurring plant succession may be sufficient. This is the least expensive management approach, but a longer time is involved and the result may not be desirable. Between these two viewpoints, there is a wide area to apply our present knowledge of ecological principles to manage subalpine grasslands.

Conclusions

th management, the "practically
ueless" subalpine ranges in the
allowa Mountains, depleted by
regulated sheep and cattle grazing
m 1880 to the early 1900's, have
eatly improved, as documented in
s and other studies. Yet, further im-
ovement and successional develop-
nt seems possible. "Sammy," as
Sampson was known to friends,
ovided the beginning. It is the
sponsibility of today's managers to
ntinue the work and the study to
. .provide a contribution to range
nagement that is of real
portance."

Acknowledgments

The authors are indebted to many people. Special credit goes to David F. Costello and Robert W. Harris, USDA Forest Service (retired), who helped in the rephotography, measured plant cover and composition, and made notes on the recovery observed during Dr. Sampson's revisit in 1955. We thank Jon Skovlin, Paul Edgerton, and Edward Dealy, Pacific Northwest Forest and Range Experiment Station, and Burt McConnell, Pacific Southwest Forest and Range Experiment Station (retired), for their help in relocating 1907 photograph points, assisting in plot work, and our use of them for carrying heavy gear on the long hikes into the study areas. The efforts of many Wallowa-Whitman National Forest personnel who wrangled horses, cooked, and helped the senior author escape late summer blizzards, is greatly appreciated. Lastly, we thank the Wallowa-Whitman National Forest, the Pacific Northwest Section, Society of Range Management, and, particularly, Victor Kreimeyer, Forest Service, Pacific Northwest Region (retired), who provided valuable and timely support for the establishment and dedication of the A.W. Sampson memorial plaque and monument.

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ppendix

ommon and Scientific Names Plant Species in the Study Areas[1]

ees and Shrubs

gelmann spruce	*Picea engelmanni* Parry
use whortleberry	*Vaccinium scoparium* Leiberg
gepole pine	*Pinus contorta* Dougl.
untain hemlock	*Tsuga mertensiana* (Bong.) Carr.
alpine fir	*Abies lasiocarpa* (Hook.) Nutt.
tebark pine	*Pinus albicaulis* Engelm.

asses

ine timothy	*Phleum alpinum* L.
tgrass	*Agrostis variabilis* Rydb.
tlebrush squirreltail	*Sitanion hystrix* (Nutt.) Smith
lifornia brome	*Bromus carinatus* Hook. & Arn.
nmon timothy	*Phleum pratense* L.
en fescue	*Festuca viridula* Vasey
ho fescue	*Festuca idahoensis* Elmer
ntucky bluegrass	*Poa pratensis* L.
e western needlegrass	*Stipa occidentalis* Thurb. *minor* (Vas.) Hitch.
top	*Agrostis alba* L.
nder hairgrass	*Deschampsia elongata* (Hook.) Munro
ke trisetum	*Trisetum spicatum* (L.) Richter
ber danthonia	*Danthonia intermedia* Vasey
stern needlegrass	*Stipa occidentalis* Thurb.

dges and Rushes

uptbeak sedge	*Carex abrupta* Mackenzie
ter sedge	*Carex vesicaria* L.
nhead	*Carex phaeocephala* Piper
sedge	Carex geyeri Boott
m's Rocky Mountain dge	*Carex scopulorum* Holm
od sedge	*Carex hoodii* Boott
ry rush	*Juncus parryi* Engelm.
ynolds sedge	*Carex raynoldsii* Dewey
ss sedge	*Carex rossii* Boott
rra-hare sedge	*Carex leporinella* Mackenzie

rbs

owleaf groundsel	*Senecio triangularis* Hook.
lifornia falsehellebore	*Veratrum californicum* Durand
quefoil	*Potentilla* spp.
sick speedwell	*Veronica cusickii* Gray
uglas knotweed	*Polygonum douglassii* Greene
nleaf licoriceroot	*Ligusticum tenuifolium* Wats.
weed	*Epilobium angustifolium* L.
rcap moss	*Polytrichum juniperinum* Hedw.
rstem groundsmoke	*Gayophytum ramosissimum* Nutt.

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[1] pecies listed are those recorded on plots at Standley Spring and Sturgill Basin, 1973-1976. With only two exceptions, botanical menclature follows Hitchcock and Cronquist (1973). *Carex abrupta* and *Polytrichum juniperinum* were identified by F. J. Hermann, Forest rvice Herbarium, Fort Collins, Colorado.

Forbs, continued

lanceleaf springbeauty	*Claytonia lanceolata* Pursh
leafybract aster	*Aster foliaceus* Lindl.
littleflower penstemon	*Penstemon procerus* Dougl.
monkeyflower	*Mimulus* spp.
needleleaf sandwort	*Arenaria aculeata* Wats.
nettleleaf gianthyssop	*Agastache urticifolia* (Benth.) Kuntze
orange agoseris	*Agoseris aurantica* Greene
Pacific onion	*Allium validum* Wats.
pearleverlasting	*Anaphalis margaritacea* (L.) B. & H.
peregrine fleabane	*Erigeron peregrinus* (Pursh) Greene
pokeweed fleeceflower	*Polygonum phytolaccaefolium* Meisn.
shootingstar	*Dodecatheon* sp.
sitka valerain	*Valeriana sitchensis* Bong.
skunkleaf polemonium	*Polemonium pulcherrimum* Hook.
skyrocket gilia	*Gilia aggregata* (Pursh) Spreng.
sulfur penstemon	*Penstemon attenuatus* Dougl.
thickstem aster	*Aster integrifolius* Nutts.
umbellate pussypaws	*Spraguea umbellata* Torr.
umber pussytoes	*Antennaria umbrinella* Rydb.
western coneflower	*Rudbeckia occidentalis* Nutt.
western yarrow	*Achillea millefolium* L.
woolly pussytoes	*Antennaria lanata* (Hook.) Greene

ocation Maps of andley Spring nd Sturgill Basin

additional objective of this paper s to bring together, under one er, Sampson's original otographs of the subalpine sslands at Standley Spring and rgill Basin. Our purpose was two- d:

To provide an easily-obtained repository of the photographs in case the file photographs or negatives are either lost or destroyed. Continuation of future rephotography and comparison would thereby be assured.

To provide anyone—hunter, backpacker, ecologist, range scientist—the opportunity to observe and compare present vegetation and range conditions with those in the past. Many people do not realize that range conditions were so much worse in earlier days than they are now, nor do they have many opportunities to observe those conditions. The photographs will provide the historical perspective. To quote Winston Churchill, "Those who fail to study history, are doomed to live it over."

ures 19, 20, and 21 will help itors access Standley Spring and rgill Basin and relocate the otographed sites.

best access to both areas, by t, horseback, or cycle, is by Trail 1677 from the end of the Big Can- Road near Bear Wallowa Spring 19). The Big Canyon Road leaves te Highway 82 one mile east of um, Oregon, and proceeds south miles to road's end. From here, the l follows a ridge 5 miles, and rises 1,75 ft to the 7,300-ft level at ndley Spring. Trail No. 1680 con- ies along the same ridge 6 miles Sturgill Basin at 7,450 ft. Named "Washboard Trail," there are y but minor elevational changes. les are prohibited from this and following trails as they enter the le Cap Wilderness.

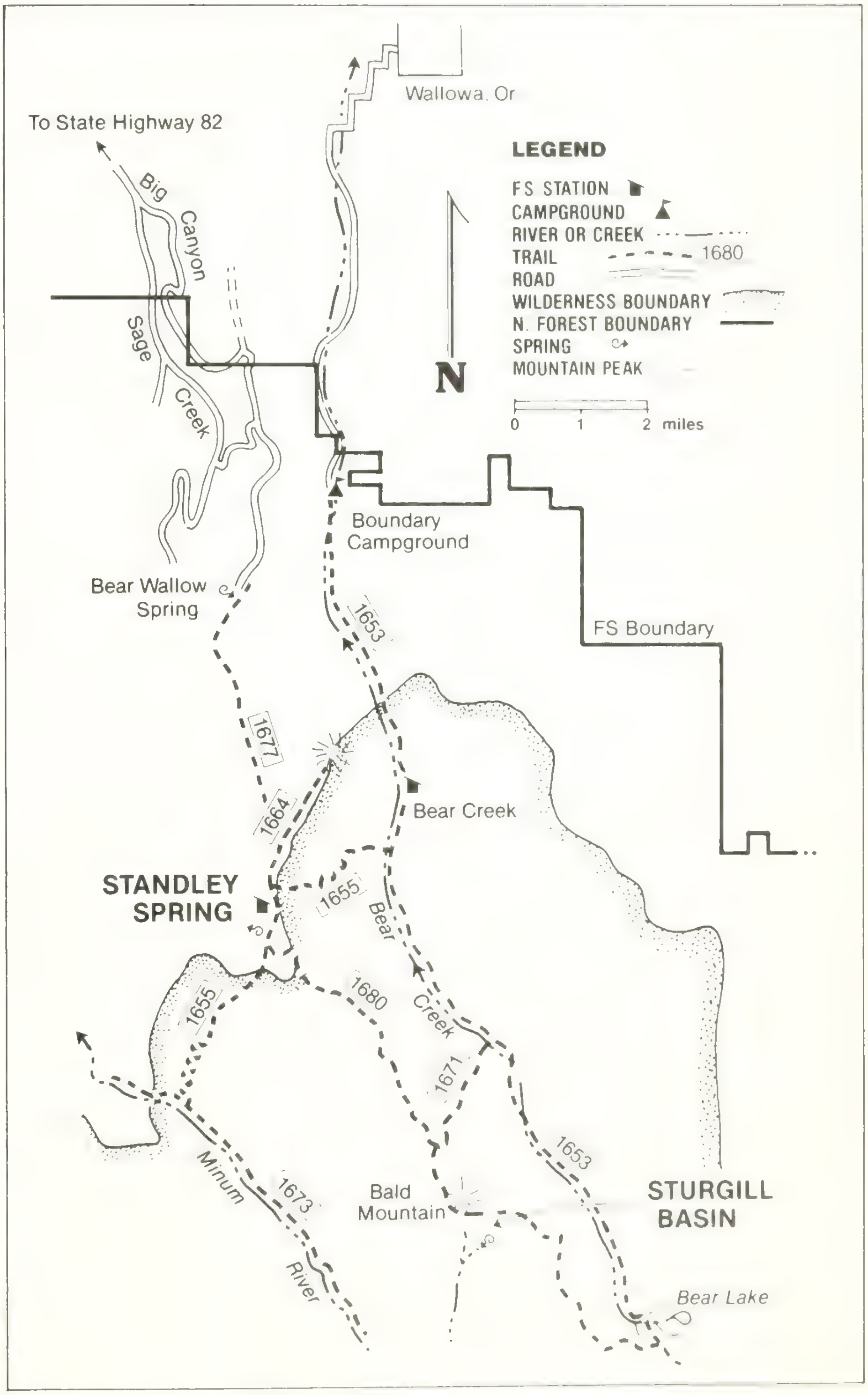


Figure 19. *Location of Standley Spring and Sturgill Basin.*

Both study areas are also accessed via the Bear Creek Trail (No. 1653) beginning at the Boundary Campground, 7.5 miles south of Wallowa, Oregon. Trail distances are greater, however, and the elevational rise is steeper; from Bear Creek to the ridge near both study areas, the elevational rise is 2,700 ft on Trail No. 1655, and 2,150 ft on No. 1671. The distance to Sturgill Basin via Bear Lake is approximately 18.5 miles.

Camera points at Standley Spring and Sturgill Basin, and some physical, topographical, and landscape features that will aid in relocating camera points are shown in figures 20 and 21, respectively. The camera points are marked with metal stakes. The viewing direction is given in the appropriate figure caption. For the more serious student, detailed maps of the study areas are filed at the Range and Wildlife Habitat Laboratory, La Grande, Oregon. Road, trail, and camping information is obtainable from the District Ranger, Wallowa Valley Ranger District, Wallowa-Whitman National Forest, P.O. Box 490, Enterprise, OR 97828.

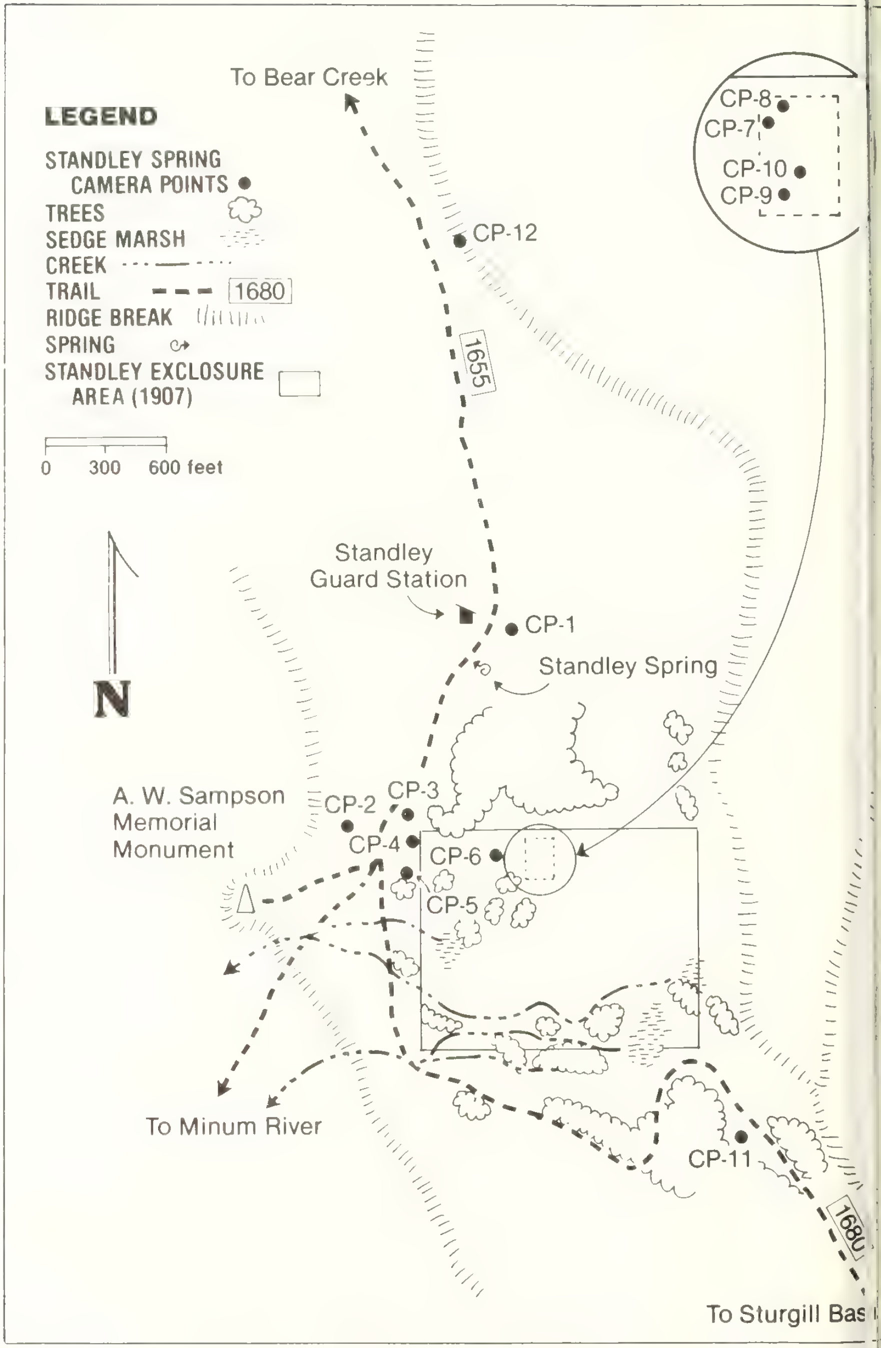
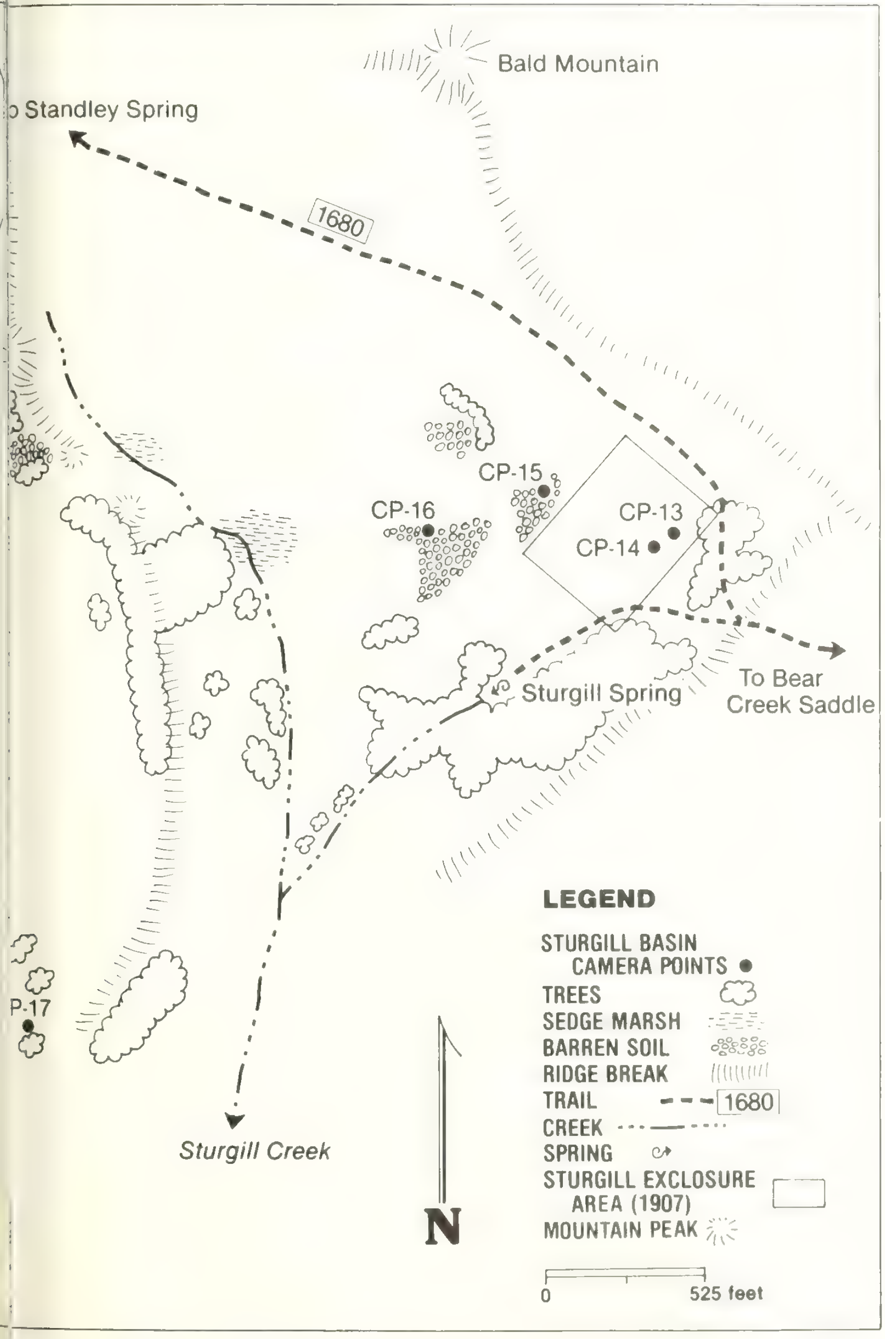


Figure 20. *Camera points (CP) at Standley Spring.*



F ure 21. *Camera points (CP) at Sturgill Basin.*

Strickler, Gerald S., and Wade B. Hall. 1980. The Standley alottment: A history of range recovery. USDA For. Serv. Res. Pap. PNW-278, 35 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

One of the first range research programs on National Forest lands was done by Arthur W. Sampson in the Wallowa Mountains, Oregon, between 1907 and 1911. The historical perspective and the basic range management principles and practices developed from the studies are reviewed. Plant succession and range improvement from the depleted conditions prevalent in 1907 are discussed and documented by photographs between 1955 and 1976.

Keywords: Range management, history (range research), revegetation (range) succession, subalpine ranges, *Festuca viridula*, grazing damage.

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

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CPO 992-121

United States
Department of
Agriculture

Forest Service

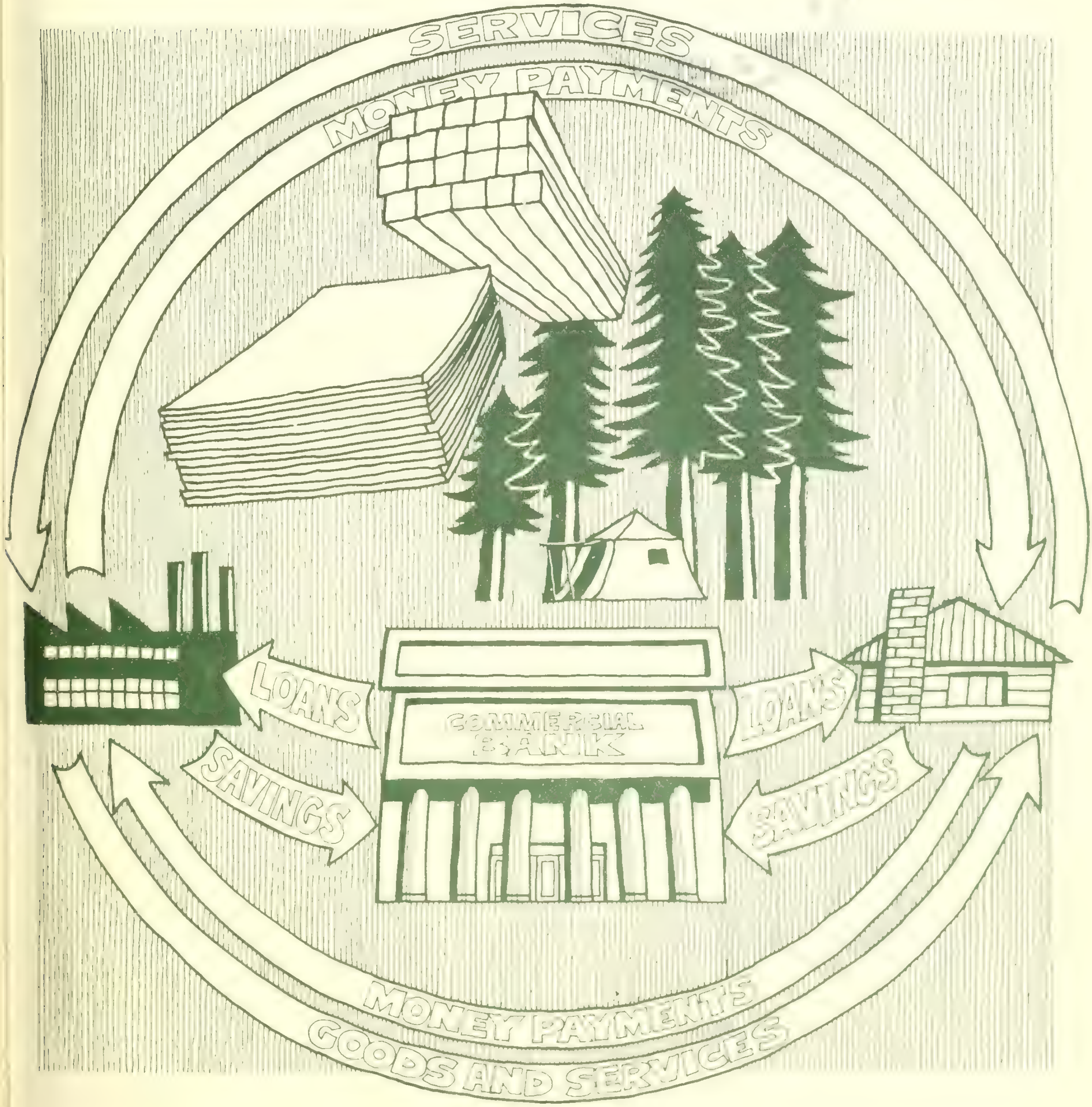
Pacific Northwest
Forest and Range
Experiment Station

Research Paper
PNW-279

November 1980

Stages of Growth Theory and Money Flows From Commercial Banks in Timber-Dependent Communities

Con H Schallau



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Acknowledgments

Acknowledgements are due to several reviewers of early drafts of this paper Comments and suggestions from Kent Connaughton, Wilbur Maki, Stanley Sackett, and Gary W. Smith were particularly helpful.

Stages of Growth Theory and Money Flows From Commercial Banks in Timber-Dependent Communities

Reference Abstract

Schallau, Con H
1980. Stages of growth theory and money flows from commercial banks in timber-dependent communities. USDA For. Serv. Res. Pap. PNW-279, 16 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

The flow of funds from commercial banks in western Oregon may indicate how a timber shortfall will affect community stability. Results suggest the inappropriateness of a single public forest management policy.

Keywords: Economic theory (-forest management, economic impact, economic growth, management planning (forest), policy (forest), Oregon (western).

Research Summary
Research Paper PNW-279
1980

Barring a major change in public and private forest management policy, western Oregon can anticipate a substantial shortfall in log production during the next two decades. The extent to which this shortfall might influence employment is uncertain. A continuing influx of new industries could provide jobs for workers laid off by the wood-using industries. But it is quite likely not all communities will benefit from the expected growth of western Oregon.

Current regulations require that USDA Forest Service planning embrace the concern for community stability. Departures from the timber-base harvest schedule can be considered when a community would be adversely impacted by strict adherence to current policies. This study examines the flow of funds from commercial banks as a possible means for determining how various timber-dependent communities might respond to the anticipated timber shortfall.

Loan-to-deposit ratios and outflow elasticities were used to trace the flow of funds. Unlike the remainder of western Oregon, both indicators disclosed a protracted outflow of funds from commercial banks in the Medford and Roseburg areas.

In light of other indicators, the outflow of funds observed in the Medford and Roseburg areas is unusual. Growth in population and per capita income exceeds the average for the State of Oregon. Furthermore, lending by other major financial institutions in all of western Oregon has grown substantially in recent years. But these differences in trends can be reconciled in terms of the stages-of-regional-growth theory. That is, the protracted outflow of funds from commercial banks may indicate that the Medford and Roseburg areas have advanced to a more mature stage of development than other timber-dependent communities in western Oregon. If so, forest resource management policies designed to achieve economic stability elsewhere may not be appropriate for the Medford and Roseburg areas.

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Introduction

Regulations recently issued by the U.S. Department of Agriculture regarding land and resource management planning in the National Forest System (36 CFR Part 219) stipulate that community stability be considered when assigning regional objectives to designated forest planning areas (Section 219.4 (b) (2)). Regarding timber, the regulations stipulate that departures from the "base harvest schedule"[1] will be considered when, "Implementation . . . would cause a substantial adverse impact upon a community in the economic area in which the forest is located," (Section 219.13 (iii) (B)). Currently, there is no acceptable means for determining the long-term consequences of a base harvest schedule on community stability. Until we develop such a mechanism, we will not be able to rationalize departures in terms of community impacts.

Given the rapid growth of Oregon's economy during the past decade, economic stability of timber-dependent communities would seem unlikely to be of concern. But what about the future? Although Oregon's economy is diversifying the timber industry still dominates--particularly outside the Portland area. Furthermore, several studies have predicted that unless private and public forest management policies are radically altered, western Oregon will experience a significant log production shortfall within the next 10 to 15 years. Beuter et al. (1976), for example, forecast a 21-percent decline in timber harvesting in western Oregon between 1980 and the year 2000. In fact, log production data suggest that the decline has already commenced. Average annual production for the 1971-1975 period was 5-percent lower than for the previous 5-year period (Brodie et al. 1978).

The shortfall will not be uniform throughout western Oregon. Current log production in the northern coastal area can probably be maintained indefinitely, whereas the Eugene area will experience a 40-percent decline. Log production in the Roseburg and Medford areas is forecast to decline about 20-percent.

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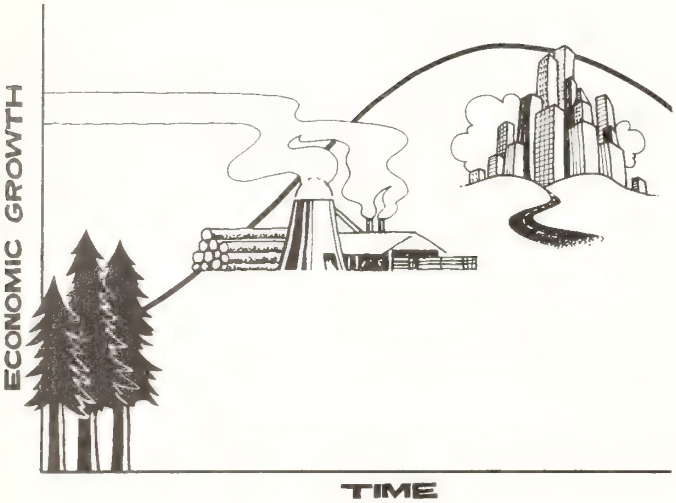
[1] "Base timber harvest schedule: The Timber Harvest Schedule in which the planned sale and harvest for any future decade is equal to or greater than the planned sale and harvest for the preceding decade of the planned period and this planned sale and harvest for any decade is not greater than long-term sustained yield capacity." 36 CFR Part 219 National Forest System Land and Resource Management Planning, Section 219.3.



Stage of Development an Important Consideration

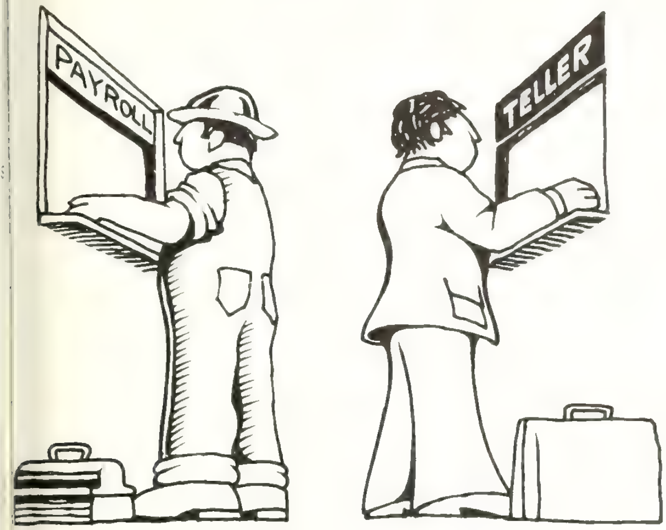
The magnitude of the expected shortfall will help identify economic communities that could be adversely affected. But it is conceivable that departures from the "base harvest schedule" could be justified for say, the Roseburg area and not the north Willamette Valley even though the Roseburg area is not expected to experience as sharp a decline in timber production. A growing, diversifying economy will more likely be able to absorb a reduction in timber production than a slower growing, more timber-dependent area. In other words, a shortfall in timber production will undoubtedly play a significantly different role depending upon an area's stage of development (Castle and Youmans 1968). Consequently, information regarding an area's stage of development is essential in determining whether or not the base harvest schedule would cause economic hardship.

Analyzing the flow of funds is one way to identify an area's stage of development. The flow between areas serves to equalize the rates-of-return among competing investment opportunities. Consequently, the relative strength of an economy can be judged on the basis of its net lending position. As Borts (1971, pp. 189-217) points out,

> Capital will flow from areas of high savings and low investment to areas of low savings and high investment. To the extent that investment levels are related to rates of growth, this means the capital also will flow from slowly to rapidly growing regions.

To properly identify an area's stage of development, one must examine economic change over an extended period. Romans (1965), for example, observed a 30-year period, 1929-59. The examination should also consider movement of capital stocks as well as money flows. Such an analytical task at the region or state level is formidable, but possible. At the sub-state level, however, the lack of accessible, economic time series data prevents a comprehensive analysis. Hence, the need for a less rigorous technique (i.e. involving fewer variables). In this paper, I examine the flow of funds from commercial banks as a possible indicator of the growth potential of timber-dependent communities.

Strategic Role of Commercial Banks n Rural Areas



Commercial banks are often the most important financial institution in rural areas, but as Verbrugge (1976) observed, "Commercial banks, regardless of size, do not typically provide the long-term credit needed for capital expansion." Though their funds may not be large compared to industry's total needs, the role of commercial banks in promoting the expansion of the economic base can be pivotal (Tweeten and Brinkman 1976). As Mittleider and Helgeson (1978) observed,

> The financial performance of banks . . . can have a direct bearing on the economic development which takes place . . . since the location of new industry may be determined by the availability of credit for its operations as well as for its employees, customers, and suppliers.

Banking Activity in Western Oregon

For the purposes of this analysis, I divided western Oregon into eight sub-areas (figure 1). These sub-areas coincide with those delineated by Maki et al. (1968). Banking data were obtained from the annual reports of the Oregon Superintendent of Banks. These

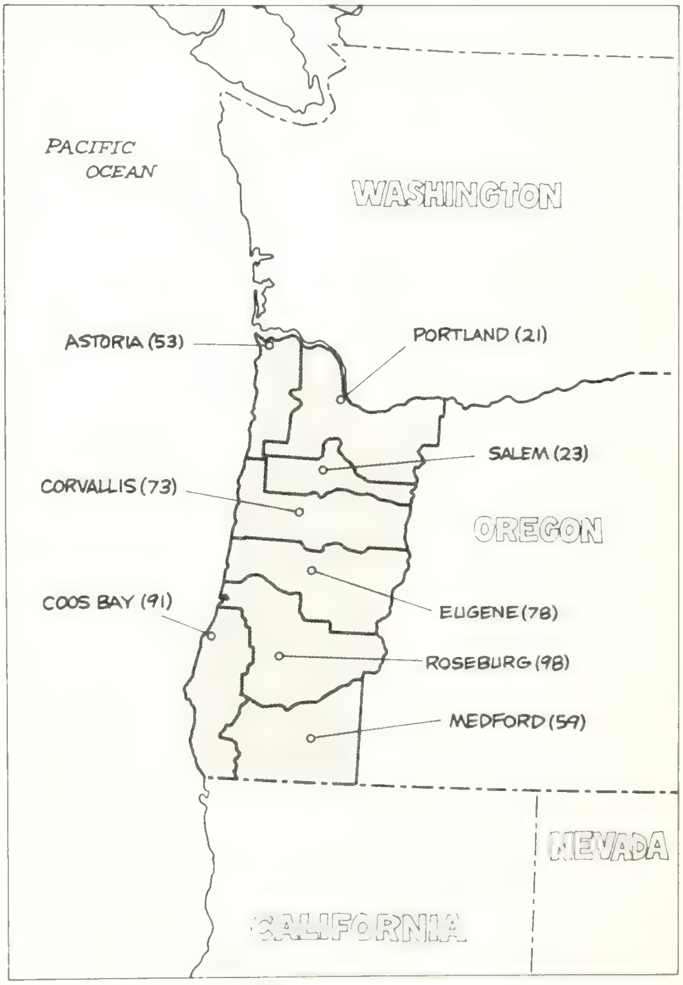
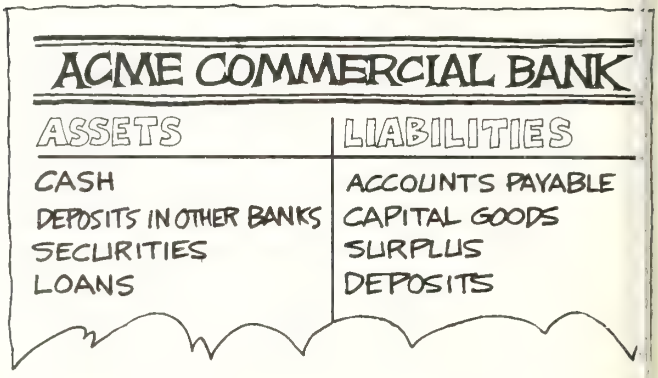


Figure 1.--Eight sub-areas in western Oregon. Numbers in parenthesis are 1971 timber-dependency indices or the percent of a sub-area's excess employment accounted for by the lumber and wood products industry. Cf., Wilbur R. Maki and Dennis L. Schweitzer (1973).

reports provide the status of loans and deposits, as of December 31, for each bank--including individual branches--in Oregon.[2] This analysis was for a 25-year period, 1953-1977. In order to avoid short-term aberrations resulting from changing monetary policy, I summarized loan and deposit data for 5-year intervals.

Savings and lending activities at commercial banks in Oregon increased substantially between 1953 and 1977. In constant 1967 dollars, total deposits in commercial banks in Oregon during the 5-year period 1953-57 averaged $2.3 billion,[3] whereas during the 1973-77 period, they averaged $4.4 billion, or an increase of nearly 90 percent. Between 1953 and 1977, lending increased by nearly the same dollar amount--from $1.1 to $3.0 billion. But in percentage terms, growth in lending exceeded saving by a substantial margin. With the exception of the Astoria area, growth of lending relative to savings was evident throughout western Oregon (figure 2). But absolute and percentage changes can be misleading regarding the flow of funds.



ACME COMMERCIAL BANK

ASSETS	LIABILITIES
CASH	ACCOUNTS PAYABLE
DEPOSITS IN OTHER BANKS	CAPITAL GOODS
SECURITIES	SURPLUS
LOANS	DEPOSITS

Banks Commit Some Funds to Non-Local Use

A fundamental maxim of banking is the avoidance of non-earning assets. This is apparent from table 1 which describes what happens when a hypothetical bank receives a new demand deposit of $100. The three-step sequence corresponds to numbers on the balance sheet:

Step (1) A new demand deposit of $100 is shown as a bank liability. The corresponding asset account has two components: (a) required reserves--$10 assuming a 10-percent marginal rate, and (b) excess reserves of $90.

Step (2) For all intent and purposes, a significant share of the excess reserve account is depleted instantly. In this example, the bank "creates" new money by loaning $60 (i.e., the new demand deposit). The customer can then draw funds from the balancing liability account.

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[2] The State's two large branch banks--First National Bank of Oregon and the U.S. National Bank--changed reporting procedures for the period 1973-77. Consequently, the annual report data for 1973-77 does not coincide with earlier periods. But with the banks' assistance, I was able to construct consistent loan and deposit series for the entire 25-year period.

[3] Unless otherwise specified, all bank transactions are reported in constant 1967 dollars. The Bureau of Labor Statistic's Consumer Price Index for all urban consumers in Portland, Oregon was used to deflate actual transactions.

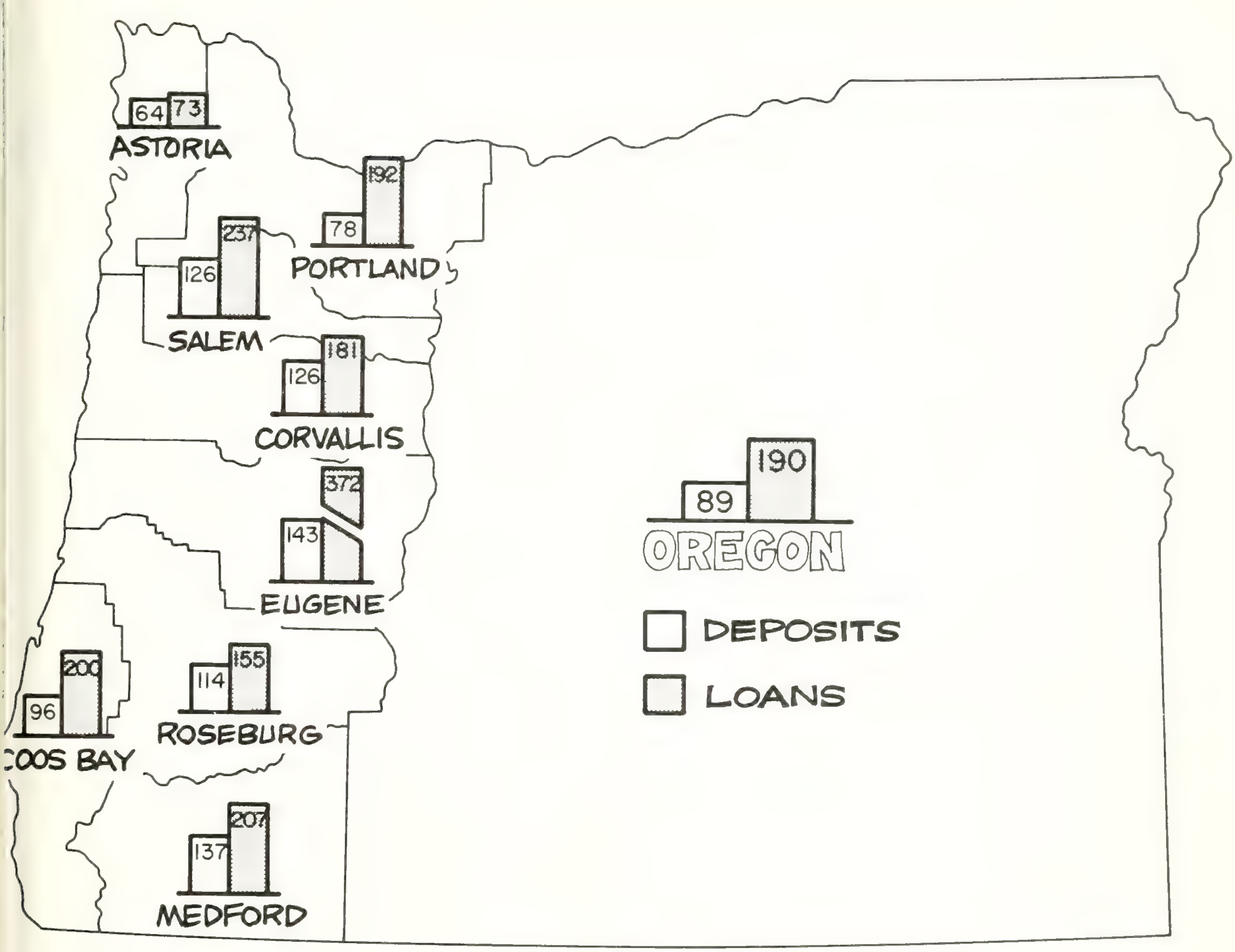


Figure 2.--Change in saving and lending activity at commercial banks for Oregon and selected sub-areas, 1953-1977 (percent).

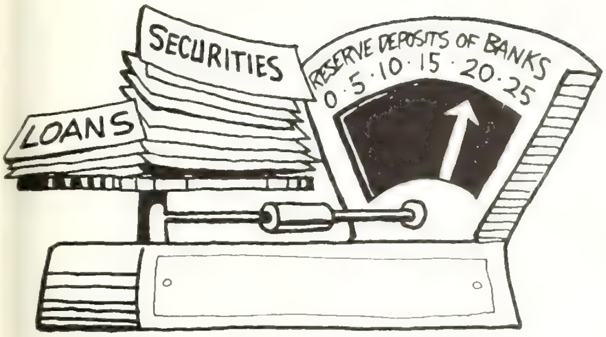
Table 1 -- The relationship between demand deposits, loans, reserves, and non-locally committed funds

Hypothetical commercial bank			
Assets		Liabilities	
(1) Reserves		(1) Demand deposits	+$100
Required	+ 10		
Excess	+ 90		
	+$100		
(2) Loan	+ 60	(2) New demand deposit	+ 60
Reserves		Existing demand deposit	100
Required			
on new deposit	+ 6		
on existing deposit	10		
Excess	84		
	$160		$160
(3) Loan	60	(3) Demand deposits	160
Reserves			
Required	16		
Excess	25		
Bonds and securities	+ 59		
	$160		$160

Note that total bank liabilities have increased to $160. On the asset side of the ledger, marginal reserve requirements must be increased $6 to cover the new demand deposit, bringing the total to $16. The bank still has assets, net of reserve requirements and loans, totaling $84. Here I'm assuming the bank chooses not to provide additional loans because (a) the remaining local investment opportunities fail to meet its earning and risk requirements, and/or (b) the bank wishes to maintain a short-term liquidity position.

Step (3) Commercial banks generally don't maintain large cash and other non-earning balances. Instead they commit funds to short-term interest-earning bonds and securities. In this hypothetical case, $59 is used to purchase bonds and securities, leaving only $25 in the excess reserve account. In rural banks, most of the $59 would represent a flow of funds from the local economy. An exception might be a locally purchased municipal bond.

To recapitulate: The initial demand deposit of $100 allowed the bank to create new money ($60) in the form of a loan to a local customer. This hypothetical bank could have created additional funds had local loan opportunities existed. They did not, so some bank funds (approximately $59) flowed from the local economy.



Loan-to-Deposit Ratio --A Money Flow Indicator

The flow of funds from commercial banks is a continuous phenomena--but the magnitude changes. The focus of this study is the change in the rate of flow. In a related study, Shane (1972) used the loan-to-deposit ratio (LDR) as an indicator of change.[4] As he observed, ". . . the alternative to making loans is buying bonds. A low LDR, particularly for a rural bank, implies an outflow of funds from the local community of greater magnitude than a higher ratio (since a loan is generally made to a member of the local community while the bond purchase is unrelated to the local community)."

Since Shane conducted his study, the general level of the LDR has increased. Commercial banks can now "buy" deposits by issuing certificates in the money market (Marple and Parks 1979). Consequently, they no longer maintain as much liquidity. But, the LDR continues to vary significantly from one locality to another. For example, in 1978 the average for member banks of the Twelfth Federal Reserve District ranged from 70.73-percent in Nevada to 89.38-percent in Washington (table 2).

Table 2 -- Loan-to-deposit ratios for member banks of the Twelfth Federal Reserve District, 1978, by State[1]

State	Ratio (percent)
Washington	89.38
California[2]	83.69
Arizona	82.07
Oregon	80.55
Utah	79.82
Idaho	79.29
Alaska	76.77
Nevada	70.73

[1] Data source: Federal Reserve Bank of San Francisco, "Western Economic Indicators," March/April, 1979, 53 pp.

[2] Includes Hawaii.

Although the change in the LDR can provide an indication of the rate of change in the flow of funds from banks, it is not altogether revealing. A decrease in the ratio indicates an increase in the rate of outflow, but an increase in the LDR may conceal an absolute decrease in the outflow. Furthermore, the change in the LDR can be misleading. For example, it is mathematically possible for the change to be negative--indicating an increase in the outflow of funds--when, in fact, the outflow decreased. Such a circumstance could arise if both loans and deposits decrease.

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[4] Shaffer (1978) used the LDR as an indicator of bank investment policy.

Outflow Elasticities Add Precision

I have used Shane's LDR technique. But to obtain a more precise measure of the change in outflow of funds and to avoid possible inconsistencies arising from the use of LDR, I also calculated "outflow" elasticities (E) which show the percentage change in non-locally committed funds (i.e., deposits minus loans)[5] associated with a 1-percent change in deposits. Symbolically, this relationship can be expressed as follows:

$$E_{j,\, j-1} = \frac{\dfrac{o_j - o_{j-1}}{o_{j-1}}}{\dfrac{D_j - D_{j-1}}{D_{j-1}}}$$

where,

$E_{j,\, j-1}$ = the outflow elasticity between time interval j and j-1.

(j = 1 . . . 5), where j is defined as follows:

j	time interval
1	1953-1957
2	1958-1962
3	1963-1967
4	1968-1972
5	1973-1977

o_j = the average outflow of funds (i.e., not committed locally) for time interval j.

D_j = the average deposits for time interval j.

Flow of Funds From Timber-Dependent Communities Varies by Sub-Areas

The average LDR for all commercial banks in Oregon increased throughout the 25-year period, 1953-77 (table 3). But this trend conceals some important differences between selected sub-areas in western Oregon. For the Salem and Portland areas, local lending opportunities attracted an increasing percentage of local bank deposits throughout the 25-year period. But for several areas--Astoria, Corvallis, Roseburg, and Medford--the LDR peaked during the 1963-67 period. Subsequently, however, LDRs for the Astoria and Corvallis areas increased during the 1973-77 period but continued to decrease in the Roseburg and Medford areas.

The outflow elasticities go beyond confirming trends suggested by the LDR indicator. As shown below, a positive change in LDR could be associated with a positive change as well as a negative change in the outflow of funds:

Value of E	ΔLDR	Indicates[6]
$E > 1$	-	Change in outflow of funds greater than increase in deposits
$0 < E < 1$	+	Change in outflow of funds less than increase in deposits
$E < 0$	+	Absolute decrease in outflow of funds associated with increase in deposits

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[5] As shown in Table 1, not all of the difference between loans and deposits represents funds leaving the local area. With the exception of the purchase of local municipal bonds--not a major item in rural areas--the difference does represent non-locally committed funds.

[6] For all sub-areas, deposits increased throughout the 25-year period, 1953-77. Had there been a decrease in deposits, the relationship between ΔLDR and elasticities (E) would have changed. The advantage of using both indices is that a different combination of LDR and E alerts one of a possible change in the significance of the indicator's sign.

able 3--Loan-to-deposit ratios for commercial banks in Oregon and selected economic ub-areas, 1953-77 (percent)

Time Period	State of Oregon	Portland	Astoria	Salem	Corvallis	Eugene	Roseburg	Medford	Coos Bay
953-1957	44.43	44.78	36.46	34.26	42.72	37.52	41.15	41.75	41.30
958-1962	50.46	53.38	38.79	35.38	48.38	49.83	39.61	46.03	48.42
hange from previous period	6.03	8.60	2.33	1.12	5.66	12.31	-1.54	4.28	7.12
963-1967	59.41	60.03	40.22	44.25	56.49	68.58	58.01	58.72	60.87
hange from previous period	8.95	6.65	1.43	8.87	8.11	18.75	18.40	12.69	12.45
968-1972	63.84	71.79	33.61	47.08	51.62	66.68	50.96	54.52	55.60
hange from previous period	4.43	11.76	-6.61	2.83	-4.87	-1.90	-7.05	-4.20	-5.27
973-1977	68.18	82.18	38.13	50.71	52.65	73.31	49.55	53.54	63.15
hange from previous period	4.34	10.39	4.52	3.63	1.03	6.63	-1.41	-0.98	7.55

urthermore, table 4 shows that during uch of the 25-year study period, the utflow of funds decreased relative to eposits in the Portland and Eugene reas. That is, a 1-percent increase n deposits was associated with an bsolute decrease in outflow. Quite the opposite occurred in the Medford and Roseburg areas (particularly the latter); for the 1968-1977 period a 1-percent increase in deposits has been assoicated with a greater than 1-percent increase in the outflow of funds.

able 4--Comparison of the change in loan-to-deposit ratios (ΔLDR) and their respective utflow elasticities (E) for commercial banks in Oregon and selected sub-areas

nterval[1]	Index	Oregon	Portland	Astoria	Salem	Corvallis	Eugene	Roseburg	Medford	Coos Bay
1	ΔLDR	+	+	+	+	+	+	-	+	+
	E	-.20	-.25	.39	.86	.28	-.42	1.28	.15	.18
2	ΔLDR	+	+	+	+	+	+	+	+	+
	E	.16	.30	.81	.49	.39	-.46	-.50	.09	-.09
3	ΔLDR	+	+	-	+	-	-	-	-	-
	E	.43	-.67	1.67	.76	1.46	1.25	1.86	1.44	1.70
4	ΔLDR	+	+	+	+	+	+	-	-	+
	E	-.51	-17.33	-.01	.45	.65	-.22	1.13	1.12	-.40

Interval 1 is between the 5-year periods 1953-57 and 1968-62; interval 2, between 1958-62 and 1963-67, etc.

Lending by Other Financial Institutions Unlike Commercial Bank Performance

The reason why the relative flow of funds from commercial banks in the Roseburg and Medford areas has been more pronounced than elsewhere is not readily apparent. While the outflow was increasing, employment in the wood products industry throughout western Oregon exhibited some growth (Maki and Schweitzer 1973). Furthermore, percentage growth of population and personal income for these two areas surpassed the average for the State of Oregon by a substantial margin (Bureau of Governmental Research and Service 1978 and U.S. Department of Commerce 1976). And finally, the outflow of funds from commercial banks in the Medford and Roseburg areas is contrary to the experience of Oregon's two major lending institutions--i.e., the savings and loan associations (S & L's) and the Veterans' Affairs (Veterans' loans).

Data are limited regarding savings and loan association activity at the sub-state level. Only deposit data for the period since 1975 is available.[7] But to the extent that the latter period is representative, savings and loan associations in the Roseburg and Medford areas haven't performed much differently than other non-metropolitan areas of western Oregon (table 5).

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[7] Traditionally, the difference between savings and loan association deposits and loans has been minimal. Consequentl deposit trend is a useful proxy for lending activity.

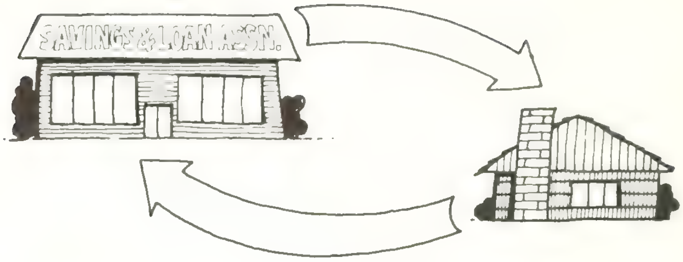
Table 5--Total deposits, in constant dollars, at savings and loan associations in selected timber-dependent areas of western Oregon[1]

Year	Astoria	Salem	Corvallis	Eugene	Roseburg	Medford	Coos Bay
	$ million						
1975	53	330	187	360	62	195	43
1976	64	369	230	421	77	241	54
1977	78	463	290	484	94	296	68
1978	91	519	331	529	108	348	78
1979	108	568	367	569	116	383	87
Change 1975-79 (percent)	103	72	96	58	88	96	100

[1] Source: Federal Home Loan Bank of Seattle. Data at sub-state level not available for previous years.

he Oregon Department of Veterans' ffairs has contributed substantially o the State's mortgage market. urrently, it is the State's largest ingle entity involved in residential ending. Although lending fell off for ome non-metropolitan areas during the 963-67 period, the annual volume ncreased steadily during the 10-year eriod, 1968-1977 (table 6). Further- ore, the growth of Veteran loans in he Roseburg and Medford areas surpassed hat for the remaining areas.

e extraordinary growth in lending by e savings and loan associations and eterans' Affairs seemingly complicates e explanation for the outflow of funds rom commercial banks in the Medford and seburg areas. But inasmuch as commer- ial banks are chartered to serve a roader range of customers, there is no eason to expect their performance to incide with that of the savings and an association or Veterans' loans.


SAVINGS & LOAN ASSN.

Whereas the latter mainly service the long-term lending needs of the residential homebuilder, commercial banks have traditionally favored the short-term market. That is, with the exception of residential mortgages, lending by commercial banks is essentially for terms of less than 5 years. The residential mortgage did account for a slightly larger share of Oregon's commercial bank lending in 1977 than in 1968 (table 7). But still, over 80-percent of lending was short-term.

able 6--Oregon veterans' loans annual activity, in constant dollars, in selected imber-dependent areas of western Oregon, 1968-1977[1]

eriod	Astoria	Salem	Corvallis	Eugene	Roseburg	Medford	Coos Bay
	$ thousand						
nnual average, 1958-1962	715	5247	3256	4758	941	2190	1067
nnual average, 1963-1967	837	4928	3083	4732	1057	1822	1119
nnual average, 1968-1972	1650	9949	6271	9401	2200	3876	2253
nnual average, 1973-1977	4145	22674	16120	27534	7038	14053	5780

Source: Oregon State Department of Veterans' Affairs.

Table 7 -- Distribution of commercial bank loans in Oregon, 1968 and 1977[1]

Type of Loan	Percent 1968	Percent 1977
Real estate		
Residential	16.1	18.2
Other	10.3	11.8
Financial institutions	5.1	9.0
Loans to individuals	20.1	21.5
Commercial and industrial	40.0	32.9
Farm	5.0	4.5
Other	3.4	2.1
	100.0	100.0

[1] Source: Federal Deposit Insurance Corporation, "Assets and Liabilities--Report of Income for Commercial and Mutual Savings Banks."

With regard to the Medford and Roseburg areas, there is reason to believe that a shrinking short-term market is responsible for the ability of commercial banks to attract savings in excess of local investing capacity. Using short-term commercial and consumer loan data for the First National Bank of Oregon and the U.S. National Bank[8]--such information for other banks was not published--short-term LDR were calculated for the 1974-1977 period. As shown in table 8, the ratio for the Medford area, unlike that for other timber-dependent areas declined throughout the 4-year period, indicating an outflow of funds resulting from a decline in short-term local lending opportunities. Furthermore, though the ratio for the Roseburg area increased, the change was less than for the remaining areas.

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[8] The two banks together accounted for approximately 63-percent of all commerc bank lending in the Medford and Roseburg areas between 1974 and 1977.

Table 8--Short-term loan-to-deposit ratios[1] for First National and U.S. National banks in selected timber-dependent areas of western Oregon, 1974-1977 (percent)

Year	Astoria	Salem	Corvallis	Eugene	Roseburg	Medford	Coos Ba
1974	18.85	34.20	32.78	45.46	34.67	47.21	33.12
1975	18.11	32.23	29.67	42.25	31.83	41.13	26.58
1976	19.18	36.72	34.76	50.01	33.36	39.51	28.59
1977	25.64	39.74	35.43	56.43	36.59	37.91	37.58
Change, 1974-1977	6.79	5.54	2.65	10.97	1.92	-9.30	4.46

[1] Total loans minus residential real estate transactions equals "short-term loans."
Source: Oregon Superintendent of Banks Annual Report.

Commercial Bank Lending May Reflect Fundamental Change

he preceding discussion provides vidence that for much of the 25-year eriod, 1953-77, local short-term ending opportunities in the Roseburg rea became increasingly unattractive o commercial banks in comparison to on-local investments. The same was he case for the Medford area during he decade commencing in 1968. For he remainder of western Oregon--articularly the Portland and Eugene reas--local lending has at least kept ace with the rate of increase in eposits. Meanwhile, even in the edford and Roseburg areas, long-term ending showed no sign of weakening.

he difference between trends in short-erm and long-term lending in the edford and Roseburg areas is too unique nd protracted to ignore. But what is he economic significance of this ifference? Might this difference elate solely to a changing role for he commercial banking industry? Or ight the performance of the commercial anks indicate more fundamental changes n the economy of timber-dependent ommunities? Let's first consider he notion of a changing role.

Industrial customers undoubtedly rely more now than previously upon non-bank financing. But aside from the fact that local banks probably have never been a major source of funds, any tendency away from this source has presumably affected all timber-dependent communities in Oregon.[9]

The rapid growth of savings and loan institutions has affected commercial banking nationwide. But competition has been more in terms of deposits rather than loans. As already noted, the commercial banks and savings and loan associations cater to different lending markets. Furthermore, there is no reason to believe that competition between commercial and savings and loan associations has been any more or less intense in the Medford and Roseburg areas than elsewhere in western Oregon.

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[9] Expenditures (in constant dollars) for new manufacturing equipment and facilities has stabilized or declined in much of western Oregon. The Portland and Eugene areas are exceptions. Between 1969 and 1973, there was a sizeable increase in the Roseburg area, but most was probably related to the construction of a single, large wood-using facility that will eventually supplant manufacturing capacity elsewhere in the Roseburg vicinity (Source: Department of Commerce, Census of Manufacturing--from published sources and personal phone conversations).

Undoubtedly, the performance of commercial banks has been influenced by all of the above, i.e., a changing role, by concentration of financial management activities, etc. But in spite of such change, one would expect a growing economy to provide increasing lending opportunities--that is, lending by commercial banks would keep pace with the growth in deposits. Clearly, this has not occurred in the Medford and Roseburg areas. In fact, the performance of commercial banks strongly suggests that the Medford and Roseburg economies are fundamentally different than other timber-dependent communities in western Oregon. In this regard, the stages-of-regional-growth theory is helpful in judging whether or not this difference is important from a forest resource policy standpoint.

Stages-of-Regional-Growth Theory and The Flow of Funds

According to the stages-of-regional-growth theory, initial development of a region's resources is accompanied by capital flows to the region (figure 3). Capital continues to flow into the economy as it diversifies, but at a decreasing rate (proliferation stage). During the industrialization stage, local investment opportunities are harder to find. In fact, the economy will become a net exporter of capital. Meanwhile, population and per capita income will continue to increase despite a leveling of export base employment. The latter phenomena may help explain why residential lending in the Medford and Roseburg areas continues to grow while commercial banks are finding local short-term lending opportunities less attractive.

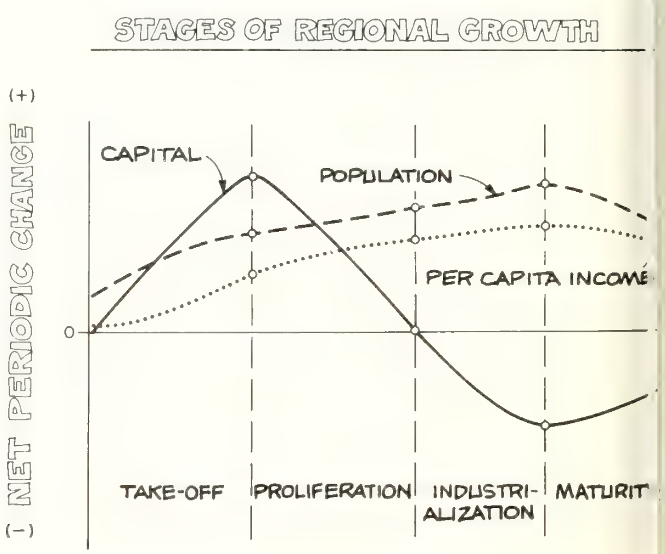
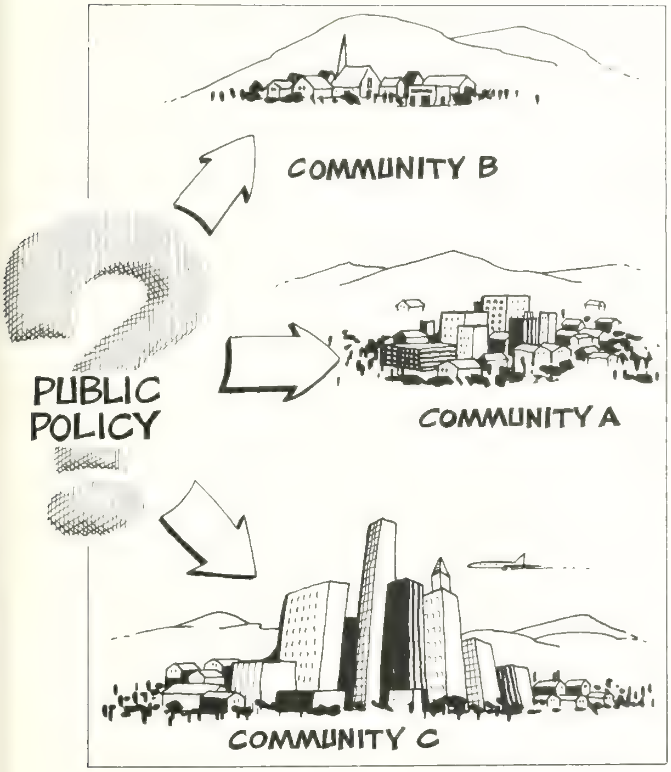


Figure 3.--According to the stages-of-regional-growth theory, net capital movement remains positive through the proliferation stage. Thereafter, net movement is outward from the region. Per capita income and population continue to increase until maturity stage. See Leven (1966) for a more detailed description of the stages-of-regional-growth theory.



Commercial banks in the Medford and Roseburg areas have been net exporters of funds for an extended period. Consequently, to the extent that commercial bank performance is indicative of capital movements in general, the Medford and Roseburg areas appear to be at a more advanced stage of development than other western Oregon timber-dependent communities.

I would conjecture that a mature, slow-growing economy is less resilient than a faster growing, diversifying economy. For timber management planning purposes, therefore, it would seem plausible to distinguish between the Medford and Roseburg areas and the remainder of western Oregon. Furthermore, a single timber management policy may not be appropriate for all of western Oregon. What might achieve community stability in one area may not elsewhere.

Devoting special attention to the Roseburg and Medford areas would be particularly timely. As mentioned previously, current regulations allow for departures from base timber harvest schedules. Also, there is evidence the potential exists for modifying public timber management policy in order to moderate the anticipated shortfall in western Oregon timber production (Beuter and Schallau 1978).

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The flow of funds from commercial banks in western Oregon may indicate how a timber shortfall will affect community stability. Results suggest the inappropriateness of a single public forest management policy.

Keywords: Economic theory (-forest management, economic growth, management planning (forest), policy (forest), Oregon (western).

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United States
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Forest Service

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Forest and Range
Experiment Station

Research Paper
PNW-280

March 1981

Postplanting Sprays of Dalapon and Atrazine to Aid Conifer Establishment

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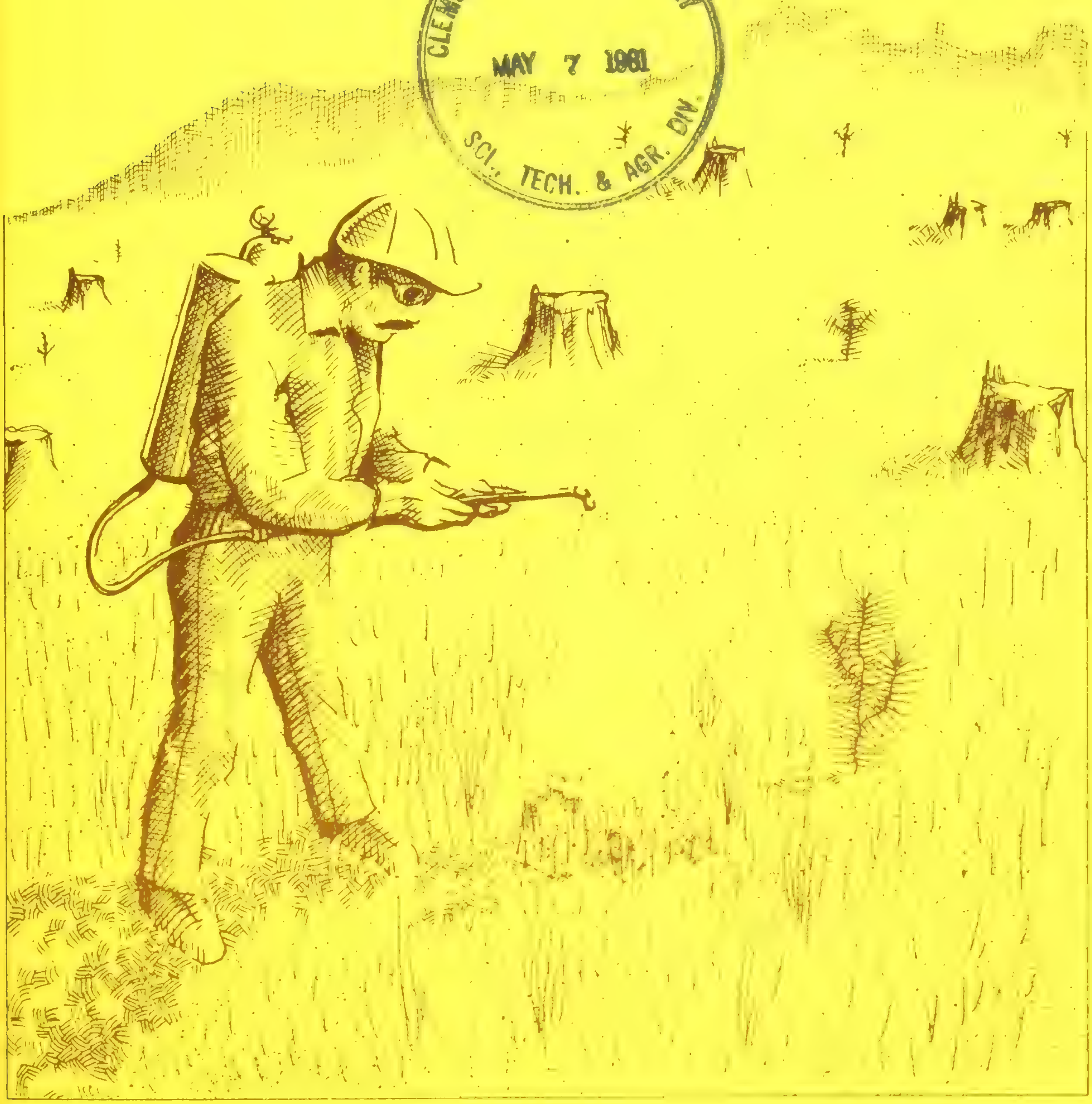

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Authors

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Abstract

Dimock, Edward J., II, and Ernest B. Collard.
1981. Postplanting sprays of dalapon and atrazine to aid conifer establishment. USDA For. Serv. Res. Pap. PNW-280. 20 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

A mixture of dalapon and atrazine consistently controlled grasses and forbs better than either herbicide used alone. Sprayed over and around newly planted ponderosa pine (Pinus ponderosa Dougl. ex Laws.) and Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco), the mixture doubled tree survival in one study, greatly enhanced height growth in another, but produced no significant gains in four studies. Protecting seedlings from herbicide sprays proved beneficial in two studies, but seemed unnecessary in four others.

Keywords: Herbicides (-regeneration, grass control, forbs, dalapon, atrazine.

Summary

Dalapon (2,2-dichloropropionic acid) and atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine], alone and in combination, were applied as postplanting sprays to control perennial grasses and forbs competing with newly planted seedlings of ponderosa pine (Pinus ponderosa Dougl. ex Laws.) and Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco).

In a series of four eastern Oregon studies, dalapon combined with atrazine at rates of 8 + 4 lb/acre (8.96 + 4.48 kg/ha) consistently controlled target species more effectively than dalapon alone at rates of 4 and 8 lb/acre (4.48 and 8.96 kg/ha). The combination reduced grass and forb cover the 1st year by averages of 80 and 58 percent, respectively, and effective control persisted for 2-3 years. Dalapon at heavier and lighter rates reduced grasses by 49 and 32 percent, respectively, during the 1st year, but effective control persisted no longer than 2 years. Dalapon alone was ineffective in controlling forbs. Covering seedlings during spraying somewhat reduced herbicide toxicity to conifers in one study, seemed unnecessary in two others, and actually reduced height growth in another. In no case was conifer survival reduced significantly below that of untreated seedlings. In one study, the dalapon-atrazine mixture doubled survival (49 vs. 25 percent) of ponderosa pine after 3 years.

A second series of two studies in both eastern Oregon and central Washington produced comparable results. Dalapon and atrazine mixed at the same rates as before reduced grasses by 82 percent and forbs by 48 percent the 1st year. Effective control of combined herbaceous species persisted 2-4 years. Dalapon at 8 lb/acre (8.96 kg/ha) reduced grasses 49 percent the 1st year but did not control forbs. Effective control of all species combined persisted for 4 years in one study but no longer than 1 year in the other. Atrazine at 4 lb/acre (4.48 kg/ha) reduced grasses 47 percent and forbs 37 percent the 1st year, with effective control of all herbaceous species persisting only about 1 year in either study. Protecting seedlings from sprays did not benefit survival but, in one study, benefited height growth of both ponderosa pine and Douglas-fir after 3 years. Covered seedlings associated with the most effective treatment (dalapon + atrazine) averaged 86 and 60 percent taller than untreated trees in ponderosa pine and Douglas-fir, respectively.

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Introduction

Resurgence and proliferation of herbaceous plants is normally rapid following forest disturbance by fire, windthrow, and logging on xeric sites east of the Cascade Range. Where disturbance is extensive or severe, land managers commonly seed annual and perennial grasses to hasten revegetation, lessen erosion, and improve forage for grazing animals. Reforesting such sites can be difficult. Delayed snowmelt necessitates planting conifers no earlier than late spring in most years; and to survive, young seedlings must compete successfully with established grasses and forbs that quickly deplete available soil moisture to critical levels with the onset of summer drought (Eckert 1979). Hence, control of competing vegetation--either before or concurrent with planting--is usually essential to minimize early mortality of young conifers in many parts of the West (Baron 1962, Christensen et al. 1974, Clark and McLean 1975, Cleary 1970, Foiles and Curtis 1973, Gratkowski et al. 1979, Hall 1971, and Heidmann 1969).

Herbicides of the *s*-triazine group have proven useful for chemically preparing reforestation sites in grassy plant communities. Atrazine, in particular, has shown notable success in substantially improving conifer survival in controlled studies (Crouch 1979, Eckert 1979, Gratkowski et al. 1979, Stewart and Beebe 1974). Certain perennial grasses and deep-rooted forbs, however, resist control by atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] (Newton 1974); and effective treatment requires at least moderate precipitation shortly after application to leach the chemical into the rooting zone of target plants. These factors, combined with posttreatment restrictions on livestock grazing, suggest that foresters could profit from even more effective and flexible alternatives. Heidmann (1970) has posited an advantage for herbicide application simultaneous with tree planting. Dalapon (2,2-dichloropropionic acid), a translocated aliphatic acid, is one herbicide with considerable potential for this type of use. Effective on a broader spectrum of perennials than atrazine, dalapon can, nevertheless, injure conifers when sprayed directly over and around young trees (Gratkowski 1976). Though such injury does not always occur (Newton 1974), Newton and Overton (1973) report that harmful effects can be masked by adding atrazine to dalapon spray formulations.

We describe six studies aimed at evaluating dalapon and atrazine, used alone and in mixture, for controlling grasses and forbs in topical applications around newly planted ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco). Four of the above studies were begun in 1975 to test spot sprays around individual seedlings planted at normal density (500/acre or 1,235/ha). The remaining two studies were started in 1976 to test broadcast sprays on small plots with seedlings planted at higher density (3,000/acre or 7,415/ha).

975 Spot Sprays
tudy Areas

ll four studies were located on the allowa-Whitman National Forest in eastern regon. One site (Camp Creek) is near nity, two sites (Devils Run and Doe Creek) ear Enterprise, and one site (Sheep Creek) ear La Grande. Soils range from silt oams or loams of sedimentary origin with inimal ash components at Camp Creek to sh-characterized loams of varying texture nd depth overlying basalt and pyroclastic ock at the other three locations. opography is rolling to nearly level at evils Run (elev., 4,900-ft or 1 490-m) and oe Creek (elev., 4,600-ft or 1 400-m), but oderately steep with northwest exposures t Sheep Creek (elev., 5,700-ft or 1 740-m) nd Camp Creek (elev., 5,500-ft or 680-m). Mean annual precipitation is: 2 in (56 cm) at Camp Creek, 20 in (51 cm) t Devils Run, 17 in (43 cm) at Doe Creek, nd 28 in (71 cm) at Sheep Creek. Mean onthly precipitation during July, August, nd September ranges from only 0.3 in 0.8 cm) to 0.8 in (2.0 cm) at all ocations except Sheep Creek where it eaches 1.2 in (3.0 cm) during September.

istory of forest disturbance before study nstallation differed on each area. ildfire had destroyed the forest overstory t Camp Creek in 1969; and much dead imber, being small and unmerchantable, emained standing and unsalvaged. The evils Run site previously supported larger rees that had been extensively windthrown n 1968 and subsequently salvaged. Timber t Doe Creek had been partially harvested n 1973 to leave a moderately stocked stand f large residual trees. Overstory on the heep Creek site had been completely arvested by clear cutting in 1973. On all ites, piling and burning of logging slash roduced only minor disturbance.

Stand composition prior to disturbance included varying proportions of ponderosa pine, Douglas-fir, lodgepole pine (_Pinus contorta_ var. _latifolia_ Engelm.), grand fir (_Abies grandis_ (Dougl. ex D. Don) Lindl.), and western larch (_Larix occidentalis_ Nutt.). Apart from residual conifers, grasses and forbs dominated each site. Principal grasses included Idaho fescue (_Festuca idahoensis_ Elm.), pinegrass (_Calamogrostis rubescens_ Buckl.), intermediate wheatgrass (_Agropyron intermedium_ (Host) Beauv.), orchard-grass (_Dactylis glomerata_ L.), and timothy (_Phleum pratense_ L.). Common forbs were heartleaf arnica (_Arnica cordifolia_ Hook.), yarrow (_Achillea millefolium_ L.), sedge (_Carex_ spp.), clover (_Trifolium_ spp.), and lupine (_Lupinus_ spp.). Sparse shrub cover, composed chiefly of shiny-leaf spirea (_Spiraea betulifolia_ Pall.), occurred only at Camp Creek.

Materials and Methods

Ponderosa pine was tested at Camp Creek and Devils Run; Douglas-fir at Doe Creek and Sheep Creek. Experimental design was identical on all sites. Each site supported an intact randomized complete block experiment with five blocks and seven treatments per block. Each treatment within a block was randomly assigned to a single row of 25 trees planted perpendicular to the land contour--providing 875 trees per experiment. Rows were spaced approximately 10 ft (3 m) apart, and 66 ft (20 m) or more separated each block. Treatments included two rates of dalapon and one rate of a dalapon-atrazine mixture. These were applied both with and without tree protection achieved by temporarily covering each seedling at time of treatment with an inverted, plugged funnel. An untreated check row completed the set:

Herbicide	Application rate [ai in lb/acre (kg/ha)]	Protection class
None (check)	--	--
Dalapon	4(4.48)	Covered
"	4(4.48)	Exposed
"	8(8.96)	Covered
"	8(8.96)	Exposed
Dalapon + atrazine	8(8.96) + 4(4.48)	Covered
Dalapon + atrazine	8(8.96) + 4(4.48)	Exposed

Ponderosa pine and Douglas-fir planting stock, grown in USDA Forest Service nurseries at Bend, Oregon, and Coeur d'Alene, Idaho, respectively, originated from seed sources local to each study area. All stock was of 2-0 class except for 525 3-0 ponderosa pine seedlings used in three blocks at Devils Run. Stock was lifted in either late March or early April, then stored at 2°C until planted in late May or early June. Where possible, each block of 175 seedlings was planted by a single worker.

Herbicides were applied by backpack sprayer to circular spots 5 ft (1.5 m) in diameter surrounding each tree about 1 to 2 weeks after planting. Dalapon used in these tests was a water-soluble powder formulation with active ingredients as sodium (72.5 percent) and magnesium (12.0 percent) salts; atrazine was an 80-percent wettable powder formulation. All herbicides were sprayed at specified rates of active ingredient in water carriers containing a non-ionic, polyglycol surfactant. Volume of carrier was 133 gal/acre (1 245 liters/ha with surfactant added at a ratio of 1:200 (v/v).

Each study was visited twice annually to evaluate target species control in early summer and conifer survival in early fall. Percentage control of herbaceous plants was based on two live crown-cover estimates made at each planting spot by adapting the method of Daubenmire (1959): 1) on the 5-ft (150-cm) treated circle, and 2) on a concentric 1-ft (30-cm) annulus immediately outside. The difference between the two was used to calculate negative or positive changes following treatment. Separate cover estimates were made for grasses and forbs. Conifer survival was the number of live trees expressed as the proportion of those originally planted. Stem heights were measured to the nearest centimeter immediately after planting and at study conclusion. All treatment means were tested by analysis of variance, and multiple comparisons were made according to Tukey's method. Camp Creek and Sheep Creek studies were monitored for two growing seasons; Devils Run and Doe Creek studies for three.

Results

Table 1--Grass control, forb control, and ponderosa pine survival and height at Camp Creek

Treatment	Grass control		Forb control		Tree survival		Stem Height
	1975	1976	1975	1976	1975	1976	1976
	Percent[1]						cm[1]
Untreated (Check)	0a	(8)a	0a	5	77	70	15.4
Dalapon, 4 lb/acre (trees covered)	31b	10ab	1a	2	75	61	15.4
Dalapon, 4 lb/acre (trees exposed)	28ab	9ab	1a	(6)	65	50	14.0
Dalapon, 8 lb/acre (trees covered)	47bc	22ab	8ab	(25)	59	45	14.6
Dalapon, 8 lb/acre (trees exposed)	47bc	28ab	4ab	(20)	74	54	14.7
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	71c	35b	54c	3	80	67	16.6
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	64c	27ab	29b	6	72	64	14.9

[1] Column means followed by the same letter or no letter do not differ significantly ($P > 0.05$). Control means not in parentheses indicate vegetation decrease; those in parentheses indicate vegetation increase. Control and survival means are based on 125 planting spots or trees; height means are for all trees surviving in 1976. 1.0 cm = 0.39 in.

amp Creek (ponderosa pine).--Grasses, omposed largely of pinegrass and fescue, ere significantly reduced by all herbicide reatments the first season (table 1). alapon combined with atrazine clearly rovided best results, but control did not ignificantly exceed that of dalapon used lone at the highest rate of 8 lb/acre 8.96 kg/ha). Recovery was rapid, and only ne combined treatment controlled grass ignificantly through the 2d year. Forbs ere not significantly reduced by dalapon lone at either low or high rates, but the alapon-atrazine combination produced ignificant reductions. No forb control as significant the second season, though a light increase in forb cover with dalapon t 8 lb/acre (8.96 kg/ha) probably occurred. Ponderosa pine survived well on all treatments the 1st year and declined from an average of 72 to 59 percent the 2d. No treatments produced significant differences in survival during either year, or in stem height after 2 years. A definite confounding of treatment effects by planting procedures was observed at Camp Creek, as treatments within each block were not planted by one individual as originally prescribed. Obvious variation in planting quality probably nullified any significant survival effects. Observable damage to ponderosa pine from herbicides did not occur in this test, and covering seedlings at time of treatment produced no benefit.

Table 2--Grass control, forb control, and ponderosa pine survival and height at Devils Run

Treatment	Grass control			Forb control			Tree survival			Stem height
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1977
	Percent[1]									cm[1]
Untreated (check)	0a	2a	3a	0a	(2)a	(15)	68	36ab	25ab	30.2
Dalapon, 4 lb/acre (trees covered)	24b	17b	5a	6a	(10)a	(8)	64	27a	15a	28.2
Dalapon, 4 lb/acre (trees exposed)	38bc	19b	7a	10a	(12)a	(9)	68	37ab	29ab	29.8
Dalapon, 8 lb/acre (trees covered)	54cd	44c	14a	14a	(25)a	(21)	80	51bc	28ab	28.0
Dalapon, 8 lb/acre (trees exposed)	62d	27b	9a	11a	(22)a	(15)	72	41abc	26ab	37.8
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	95e	74d	30b	88b	30b	(18)	80	59c	52c	32.2
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	94e	76d	35b	86b	23b	(26)	75	56bc	46bc	34.2

[1] Column means followed by same letter or no letter do not differ significantly ($P > 0.05$). Control means not in parentheses indicate vegetation decrease; those in parentheses indicate vegetation increase. Control and survival means are based on 125 planting spots or trees; height means are for all trees surviving in 1977. 1.0 cm = 0.39 in.

Devils Run (ponderosa pine).--All herbicides reduced grass cover significantly--an effect that extended through the second growing season for all treatments (table 2). Grasses included high densities of orchard-grass and intermediate wheatgrass but little pinegrass. Dalapon at 8 lb/acre (8.96 kg/ha) combined with atrazine at 4 lb/acre (4.48 kg/ha) reduced grass cover to nearly zero the 1st year, substantially inhibited its recovery, and maintained significant control through the 3d year. Dalapon used alone at either 4 or 8 lb/acre (4.48 or 8.96 kg/ha) was also effective through the second season but far less so than the combination treatment. All grass treated with dalapon alone had essentially recovered by the 3d year. Forbs were reduced only by combinations of dalapon and atrazine. Degree of control was high the 1st year and persisted at significant levels into the 2d. This result is notable because dalapon alone caused some increase in forb cover the 2d year, even though the increase was not significant.

Survival of ponderosa pine, like that at Camp Creek, was relatively high the 1st year but declined more rapidly from the same level of 72 percent in 1975 to 44 percent in 1976. More important, significant treatment-related differences, absent the 1st year, appeared in the 2d. Compared to the untreated check, dalapon used alone at low and high rates did not increase survival but the high rate combined with atrazine did. This result was significant for protected seedlings--i.e. 59 vs. 36 percent for treated and untreated trees, respectively. The margin widened to a significant doubling of survival for treated trees (52 vs. 25 percent) by the 3d year. Exposed trees treated with the same herbicide mixture survived almost equally well (46 percent), though not significantly better than the untreated check due to wide variation in treatment response.

Table 3--Grass control, forb control, and Douglas-fir survival and height at Doe Creek

Treatment	Grass control			Forb control			Tree survival			Stem height
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1977
	Percent[1]									cm[1]
Untreated (check)	0a	3a	0a	0a	(2)a	(4)	90	70	49	21.8
Dalapon, 4 lb/acre (trees covered)	18ab	19b	9a	11a	(1)a	(3)	85	72	60	24.2
Dalapon, 4 lb/acre (trees exposed)	14ab	22bc	8a	9a	1a	0	90	64	50	20.6
Dalapon, 8 lb/acre (trees covered)	22b	33c	18a	11a	1a	(4)	89	79	62	22.6
Dalapon, 8 lb/acre (trees exposed)	32b	32bc	12a	15a	(3)a	(3)	86	75	56	23.0
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	92c	81d	51b	81b	59b	18	90	77	63	24.2
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	90c	84d	46b	79b	56b	8	88	68	54	20.8

[1] Column means followed by the same letter or no letter do not differ significantly ($P > 0.05$). Control means not in parentheses indicate vegetation decrease; those in parentheses indicate vegetation increase. Control and survival means are based on 125 planting spots or trees; height means are for all trees surviving in 1977. 1.0 cm = 0.39 in.

Visible damage to treated trees did not occur in this study. Furthermore, analysis of 3d-year tree height among all herbicide treatments (less the untreated check) disclosed an unexpected growth response associated with tree protection. Trees exposed at time of spraying averaged 4.4 cm (1.7 in) taller than covered trees. Moreover, this difference was significant ($P < 0.05$).

Doe Creek (Douglas-fir).--Herbaceous cover was similar to that at Devils Run but less dense and contained a higher proportion of forbs. During the 1st year, grass was reduced significantly only by treatments containing 8 lb/acre (8.96 kg/ha) of dalapon (table 3). Even this rate of dalapon, when used alone, reduced grass cover but little. The reduction persisted through the 2d year when control with the 4 lb/acre (4.48 kg/ha) rate of dalapon also became significant. Combining dalapon with atrazine, however, produced nearly total grass control the 1st year--an effect that diminished only gradually in the 2 years following. After 3 years, grass cover was still reduced by about 50 percent and significant control by the dalapon-atrazine combination could be expected for at least another year. Dalapon used alone was ineffective in reducing competition by forbs. The higher rate of dalapon combined with atrazine, however, produced a high level of forb control that remained significant throughout the first 2 years. By the 3d year, forb control was no longer significant.

Douglas-fir survival averaged 88 percent for all treatments the 1st year after planting. Mean survival declined to 72 percent in 1976, and to 56 percent in 1977. Though herbicide-treated seedlings survived consistently better than those on the untreated check after 3 years (58 vs. 49 percent, respectively), differences among all treatments were not significant. By eliminating the untreated check, however, we can compare common effects of herbicides and seedling protection. Survival differences associated with herbicides were not significant in any year; but by the 3d year, the difference between covered (62 percent) and exposed (53 percent) trees was ($P < 0.05$). Thus, seedling protection appeared to improve Douglas-fir survival by minimizing toxicity of herbicide treatment to trees while maximizing benefits of herbicide-reduced competition. At 3 years, stem height remained unaffected by treatment.

Sheep Creek (Douglas-fir).--Conditions on this site, more mesic than those on others, produced herbaceous cover dominated by grasses and sedges with a minimal component of forbs. Dalapon significantly reduced grass and sedge competiton the 1st year for all rates used either with or without atrazine (table 4), but the range of control was narrower (50 - 68 percent) than that achieved elsewhere (tables 1 - 3). A lack of difference between effects of dalapon used alone at 8 lb/acre (8.96 kg/ha), or at the same rate with atrazine added, was especially noticeable. The herbicide mixture was the only treatment that reduced forb cover significantly. No significant control of grasses or forbs persisted through the 2d year.

A high rate of Douglas-fir survival was attained the 1st year with all treatments, and no response to treatment could be detected. Survival declined from 93 percent the 1st year to 74 percent the 2d, when treatment-related differences again failed to appear. Future gains or losses as a consequence of herbicide applications also seemed unlikely in this test. As observed on site and reflected in the data, no injury to Douglas-fir due to herbicides occurred. Tree height at 2 years was neither increased nor decreased by treatment.

Table 4--Grass control, forb control, and Douglas-fir survival and height at Sheep Creek

Treatment	Grass control		Forb control		Tree survival		Stem height
	1975	1976	1975	1976	1975	1976	1976
	Percent[1]						cm[1]
Untreated (Check)	0a	17	0a	4	95	75	18.1
Dalapon, 4 lb/acre (trees covered)	50b	24	8ab	2	90	74	16.8
Dalapon, 4 lb/acre (trees exposed)	53b	24	4ab	0	90	72	18.6
Dalapon, 8 lb/acre (trees covered)	65b	36	8ab	3	93	71	17.5
Dalapon, 8 lb/acre (trees exposed)	62b	24	4ab	0	97	78	18.1
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	68b	31	23b	8	94	79	17.4
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	64b	24	20b	10	90	72	17.5

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[1] Column means followed by the same letter or no letter do not differ significantly ($P > 0.05$). Control and survival means are based on 125 planting spots or trees; height means are for all trees surviving in 1976. 1.0 cm = 0.39 in.

Discussion

Weather was unusually favorable for conifer survival at all study locations in 1975. A cool, moist spring was followed by above-average precipitation in July and August at each site, as indicated by departures from long-term monthly averages:

Location	Precipitation July	Precipitation August	Precipitation September
	Inches or (cm)		
Camp Creek	+ 0.7 (1.8)	+ 0.3 (0.8)	- 0.6 (1.5)
Devils Run	+ 2.3 (5.8)	+ 0.8 (2.0)	- 0.8 (2.0)
Doe Creek	+ 2.3 (5.8)	+ 0.9 (2.3)	- 0.7 (1.8)
Sheep Creek	+ 0.3 (0.8)	+ 0.2 (0.5)	- 1.2 (3.0)

Prolonged drought occurred only in September, and was soon relieved by above-normal October precipitation that ranged from a total of 1.3 in (3.3 cm) at Camp Creek to 3.4 in (8.6 cm) at Devils Run and Doe Creek. Though mean summer temperatures generally exceeded normal, drought conditions were undoubtedly abated.

Moisture stresses less than normal in 1975 probably reduced the likelihood of demonstrable benefits in terms of seedling survival. For example, large differences in relative survival were attained only at Devils Run, the site at which mortality of untreated seedlings was highest. Toxicity of herbicides to ponderosa pine was not evident at either Camp Creek or Devils Run. In fact, exposed trees at Devils Run were actually outgrowing covered trees by the 3d year. Though difficult to explain, this result at least indicates no adverse effects from herbicides. Marginal toxicity to Douglas-fir was suggested only at Doe Creek after 3 years, when survival of sprayed, covered trees exceeded that of sprayed, exposed and unsprayed trees by 9 and 13 percent, respectively. In this case, the only example of benefits associated with covering of seedlings, trees sprayed with dalapon-atrazine mixtures survived no better than those sprayed with dalapon alone. In our tests, atrazine did not appear to inhibit dalapon's phytotoxicity to conifers by the antagonistic mechanisms suggested by Newton and Overton (1973). Rather, cool storage of seedlings before planting delayed their emergence from dormancy and likely minimized adverse response to postplanting dalapon sprays. Damage by dalapon (with or without atrazine) to occasional natural seedlings, inadvertently sprayed on our study areas, reinforced this impression.

Though adding atrazine did not seem to reduce dalapon's toxicity to conifers, such toxicity was of little consequence. The combination did, however, provide high levels of lasting control of both grasses and forbs. Though dalapon alone effectively controlled grasses to a varying extent in all studies, the spectrum of grass species affected was narrower. Furthermore, dalapon did not control forbs. In fact, 2d-year increases in forb cover were suggested at Camp Creek and Devils Run--presumably in response to dalapon-caused decreases in grass competition the previous year. Only dalapon-atrazine mixtures consistently produced the degree and permanence of herbaceous control likely to benefit conifers substantially. Though obvious gains in survival with such mixtures occurred solely at Devils Run, they might have occurred elsewhere had competitive factors been more limiting. Northern pocket gophers (Thomomys talpoides) caused considerable damage to planted ponderosa pine at Devils Run, and damage was associated with 31 percent of the mortality occurring there over 3 years. No differences in damage were related to spot-spray treatments, though vegetation control with herbicides on even small plots has been shown to reduce damage by pocket gophers (Crouch 1979, Stewart and Beebe 1974).

976 Broadcast Sprays

udy Areas

retest dalapon and atrazine sprays, two udies were initiated in 1976 at widely parated locations. One experiment (TNT lch) was again sited on the Wallowa-itman National Forest near Enterprise, egon; the other (Entiat River) on the natchee National Forest near Entiat, shington. TNT Gulch is less than a mile .6 km) south of the 1975 site at Devils n; and soils (ash), topography (level to lling), and mean annual precipitation (20 or 51 cm) are essentially identical. At tiat River, soils ranged from residual, h-characterized loams to light-textured mice overlying gneiss and granodiorite. pography is generally mountainous and eep near Entiat, and elevations of study ots varied from 2,700 to 3,300 ft (825 to 000 m). Mean annual precipitation at the rious Entiat locations is 18 to 22 in (46 56 cm). During July, August, and Sep- mber, mean monthly precipitation near tiat is similar to that in northeastern egon and averages below 1 in (2.5 cm). te history at TNT Gulch included 1968 owdown and salvage of forest over- ory--the same as that at Devils Run. The tiat River experiment was divided between cations at Mosquito Ridge and Preston eek, both ravaged by extensive wildfire 1970. Only scattered patches of small, re-killed timber remained at Entiat River ot locations. Herbaceous cover at TNT lch, similar to that at Devils Run, also cluded some Kentucky bluegrass (*Poa pra- nsis* L.). Sheep fescue (*Festuca ovina* L.) Entiat River replaced Idaho fescue at T Gulch, but species composition of asses and forbs in both experiments peared otherwise much alike. Shrub cover s lacking at TNT Gulch and only sparse at tiat River.

Materials and Methods

Experimental design was the same at TNT Gulch and Entiat Burn. Both ponderosa pine and Douglas-fir were tested at each location. Each experiment was a randomized complete block with three blocks of seven treatments per block. Each treatment was randomly allocated to one of seven square 1/100-acre (1/250-ha) plots. Fifteen ponderosa pine and 15 Douglas-fir seedlings were planted on each plot in six rows of alternating species with 5 seedlings per row (315 trees of each species per experiment). Untreated buffers minimally 10 ft (3 m) wide separated individual plots, and 1/2 mile (4/5 km) or more separated each block. Treatment variables in broadcast-spray studies differed in only one respect from those in spot-spray studies--i.e. substitution of atrazine for the lower rate of dalapon. Therefore, with two exceptions, the seven treatment prescriptions were identical and again included three herbicide treatments applied with and without temporary seedling protection:

Herbicide	Application rate ai in lb/acre (or kg/ha)	Protection class
None (check)	--	--
Dalapon	8(8.96)	Covered
"	8(8.96)	Exposed
Atrazine	4(4.48)	Covered
"	4(4.48)	Exposed
Dalapon + atrazine	8(8.96) + (4.48)	Covered
" + "	8(8.96) + (4.48)	Exposed

USDA Forest Service nurseries at Coeur d'Alene, Idaho, and Wind River, Washington, provided Douglas-fir planting stock required at TNT Gulch and Entiat River, respectively. The nursery at Bend, Oregon, provided all ponderosa pine. All stock was of 2-0 class and originated from seed sources local to each area. Stock was lifted in late winter or early spring, stored at 2°C, and planted in late May at TNT Gulch and early June at Entiat River. Individual planters were employed for each species on each block. Herbicides were applied by backpack sprayer 1 to 4 weeks after planting. Powder formulations of herbicide, the same as used in 1975 spot sprays, were sprayed upon entire plots at specified rates of active ingredient without surfactant in water carriers at volumes of 200 gal/acre (1 870 liters/ha).

Control of target species was rated in midsummer; survival and height of conifers in early fall. Differences in herbaceous cover, estimated to the nearest 10 percent between plots and adjacent buffer strips, were used to calculate percentage control. As in spot-spray studies, analysis of variance was used to test treatment response in separate years, and multiple comparisons were made by the method of Tukey. Results at TNT Gulch were monitored for two growing seasons. At Entiat River, vegetation control was monitored for four seasons; survival and height of conifers for three.

Results

TNT Gulch.--All herbicides reduced grass competition significantly the 1st year, and reductions attained with atrazine were somewhat greater than those attained with dalapon (table 5). Combining the two herbicides significantly increased levels of grass control beyond those produced by dalapon but did not significantly improve the performance of atrazine. Comparable to 1975 studies, dalapon did not significantly reduce competition by forbs. Atrazine, however, was successful in doing so, but the degree of control was erratic. Adding atrazine to dalapon was chiefly effective in widening the spectrum of forbs controlled--an effect observed on different blocks but not clearly reflected in treatment means. By the 2d year, combined reductions of grasses and forbs were significantly associated only with dalapon-atrazine mixtures and one of the atrazine treatments.

Ponderosa pine survived well the 1st year after planting and declined from 91 percent for all treatments to 62 percent by the 2d year. Though a survival advantage was apparent in 1977 for all herbicide treatments (64 percent) compared to the untreated check (49 percent), differences among individual treatment pairs were not significant. A much greater decline occurred between Douglas-fir survival in 1st and 2d years--82 to 20 percent; but survival differences were again not significant. Stem height of either species at 2 years remained unaffected by treatment. No observable toxicity to conifers resulted from herbicides, and no benefits from seedling protection emerged. During the 2d summer, range cattle used all parts of the study area heavily. The animals displayed a distinct proclivity for resting and bedding down on those plots where vegetation control had been most successful. Resultant damage to and mortality of seedlings on these study plots obviously confounded results. Accordingly, study evaluation was concluded after 2 years.

able 5--Vegetation control, tree survival, and stem height at TNT Gulch

Treatment	Vegetation control			Tree survival				Stem height	
	Grass	Forb	Grass + Forb	Ponderosa pine		Douglas-fir		Ponderosa pine	Douglas-fir
	1976	1976	1977	1976	1977	1976	1977	1977	
	Percent[1]							cm[1]	
ntreated (check)	0a	0a	0a	91	49	87	31	19.2	16.6
alapon, 8 lb/acre (trees covered)	43b	10ab	13ab	96	56	67	16	20.0	14.8
alapon, 8 lb/acre (trees exposed)	50b	10ab	8ab	91	64	84	9	17.9	13.5
razine, 4 lb/acre (trees covered)	67bc	60cd	30bc	84	58	82	16	16.8	14.8
razine, 4 lb/acre (trees exposed)	57bc	37bc	11ab	93	69	89	18	20.6	12.2
alapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	87c	67d	30bc	98	73	84	29	20.7	12.2
alapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	87c	70d	48c	84	62	80	22	16.5	14.7

Column means followed by the same letter or no letter do not differ significantly ($P > 0.05$). Control eans are based on 3 replicates; survival means on 45 trees. Height means are for all trees surviving in 1977. .0 cm = 0.39 in.

ntiat River.--Pinegrass was present on the wo study blocks at Mosquito Ridge, while rchard-grass, fescue, and timothy predomiated on the single block at Preston Creek. rass competition was reduced by all herbiides the 1st year, and control associated ith only one atrazine treatment failed to iffer significantly from the untreated heck (table 6). Dalapon proved somewhat ore effective than atrazine, but only the ost effective dalapon treatment produced ignificantly greater control than the east effective atrazine application. As t TNT Gulch, dalapon-atrazine mixtures esulted in greatest control of grass. ome reduction of forbs was attained with ll herbicides the 1st year, but wide data ariations precluded significance. Comining evaluation of grass and forb cover acilitated treatment comparisons in ubsequent years. Only treatments conaining dalapon produced significant vegetation reductions the 2d year. Moreover, these reductions generally persisted through the 4th year. Though dalapon-atrazine mixtures continued to produce best control, dalapon alone was almost as effective.

Survival patterns were similar for both ponderosa pine and Douglas-fir throughout the 3-year period of evaluation (table 7). In ponderosa pine, percentage of live trees remaining after planting declined from 78 percent the 1st year to 69 percent the 3d. High 1st-year survival of Douglas-fir likewise declined from 92 to 77 percent after 3 years. Within both species, mortality was slight the 2d and 3d years. Analysis did not reveal any significant survival increases or decreases associated with treatment for any year within either species.

Table 6--Vegetation control at Entiat River

Treatment	Vegetation control: Grass 1976	Forb 1976	Grass + Forb 1977	1978	1979
	- - - - - - - - - Percent[1]		- - - - - -		
Untreated (check)	0a	0a	13a	6a	(6)a
Dalapon, 8 lb/acre (trees covered)	57cd	27a	67b	40ab	21abc
Dalapon, 8 lb/acre (trees exposed)	47bc	10a	74b	64b	32bc
Atrazine, 4 lb/acre (trees covered)	40bc	17a	5a	(4)a	4ab
Atrazine, 4 lb/acre (trees exposed)	23ab	33a	6a	5a	2ab
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	83d	27a	81b	63b	39bc
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	70cd	30a	84b	63b	45c

[1] Column means followed by the same letter do not differ significantly (P > 0.05). Control means not in parentheses indicate vegetation decrease; those in parentheses indicate vegetation increase. All means are based on three replicates.

Table 7--Survival and height of ponderosa pine and Douglas-fir at Entiat River

Treatment	Ponderosa pine: Survival 1976	1977	1978	Height 1978	Douglas-fir: Survival 1976	1977	1978	Height 1978
	- - - Percent[1]		- - -	cm[1]	- - - Percent[1]		- - -	cm[1]
Untreated (check)	82	82	78	16.7a	87	73	67	17.7a
Dalapon, 8 lb/acre (trees covered)	82	69	64	22.3ab	96	82	[illegible]	17.7a
Dalapon, 8 lb/acre (trees exposed)	76	60	60	13.7a	93	82	80	15.0a
Atrazine, 4 lb/acre (trees covered)	76	73	73	20.3a	96	75	[illegible]	18.7a
Atrazine, 4 lb/acre (trees exposed)	73	67	[illegible]	17.7a	91	76	75	17.7a
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	87	87	84	31.0b	93	[illegible]	86	28.3b
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	71	65	58	18.3a	91	82	82	18.3a

[1] Column means followed by the same letter or no letter do not differ significantly (P > 0.05). Survival means are based on 45 trees; height means are for all trees surviving in 1978. 1.0 cm = 0.39 in.

erbicide treatments containing dalapon
roduced some observable damage to conifer
oliage when sprayed over exposed seed-
ings. No differences in damage could be
etected between trees sprayed with either
alapon or dalapon-atrazine mixtures.
nalysis of tree height at 3 years revealed
large and significant advantage for the
alapon-atrazine combinations if sprayed
ver covered seedlings (table 7). Pon-
erosa pine and Douglas-fir thus treated
veraged 14.3 and 10.6 cm (5.6 and 4.2 in)
aller, respectively, than untreated check
rees. If check treatments are excluded,
overed trees among all herbicide treat-
ents averaged 8.1 and 4.6 cm (3.2 and 1.8
n) taller than exposed trees--again for
onderosa pine and Douglas-fir, respec-
ively. Moreover, these differences were
ighly significant ($P < 0.01$).

Discussion

Climatic factors generally favored conifers planted in 1976. Overcast skies were common during spring, and temperatures cooler than normal prevailed during summer months. Precipitation averaged near normal in spring and early summer, but monthly departures were well above normal in August as determined from locations near the study sites:

Location	Precipitation July	 August	 September
	- - - - - - Inches or (cm)	- - - - -	
TNT Gulch (Enterprise)	+ 0.4 (1.0)	+ 2.2 (5.6)	- 0.1 (0.3)
Entiat River (Chelan)	- 0.1 (0.3)	+ 1.0 (2.5)	- 0.4 (1.0)

These departures, occurring near the midpoint of summer drought, combined with cooler weather to ameliorate factors critical to survival of newly planted conifers.

Little mortality of conifers occurred the first season at either TNT Gulch or Entiat River. Herbicide treatments aimed at enhancing survival are less likely to be effective if the factors they ameliorate are not limiting. First-year survival of untreated ponderosa pine and Douglas-fir seedlings at both locations ranged from 82 to 91 percent and left little margin for improvement. Therefore, reducing moisture stress on conifers by controlling competing grasses and forbs would likely have engendered more easily seen benefits in drier years.

Potential Application

Conifers at TNT Gulch displayed no toxic symptoms to herbicides applied either with or without seedling protection, and their survival was not significantly affected. Toxicity may have been minimized by rainfall shortly after spraying that diluted herbicide in contact with conifer foliage. At Entiat River, however, some injury to conifers was visible. Spraying dates were somewhat later than those at TNT Gulch, and conifers may have been less tolerant to herbicides. Benefits of seedling protection accrued gradually over time at Entiat River and produced gains in conifer growth but not in survival. The markedly superior growth of protected seedlings sprayed with a dalapon-atrazine mixture appears to be a net response relating to the combined effects of maximal control of target species and minimal toxicity to conifers. As in 1975 studies, adding atrazine to dalapon sprays did not appear to increase or decrease its toxicity to conifers.

trazine was somewhat more effective than alapon in controlling plant competitors at NT Gulch, but the reverse was true at ntiat River. The reversal was partly due o more efficient control of forbs with trazine at TNT Gulch, but most likely eflected the net effect of differences in eather, soils, and species composition. trazine was ineffective on either forbs or rasses after 1 year at Entiat River, and ost lasting control in both studies was ttained with dalapon-atrazine mixtures.

ode of action upon target plants was robably most responsible. Dalapon unctions chiefly by direct translocation nto foliage, while atrazine acts primarily hrough absorption by roots. Thus, com-ining the two herbicides more effectively xploited the properties of each to attain broader spectrum of lasting response nder a wider latitude of environmental onditions.

Postplanting sprays of dalapon combined with atrazine can safely and effectively control herbaceous species competing with newly planted conifers on dry, grassy sites. Postplanting sprays can be used with little or no injury to ponderosa pine and Douglas-fir, and seem a viable option to preplanting sprays that often require substantial delays between application and tree planting. The dormancy of planting stock taken from cool storage at forest nurseries can be effectively exploited in spring planting. If sufficiently prolonged, dormancy appears to provide latitude for topical applications of herbicides that might otherwise prove injurious. Chemically preparing sites in conjunction with the tree planting process has practical value for forest managers. Work scheduling can be simplified, opportunities for vegetation management expanded, and spot spraying used selectively to control herbaceous competitors only in the immediate vicinity of planted trees.

In our studies, a mixture of dalapon and atrazine (8 + 4 lb ai/acre, or 8.96 + 4.48 kg ai/ha) was the only spray treatment that significantly increased survival or growth of planted conifers. Temporary covering of seedlings at time of spraying provided some additional benefit but may not have been necessary in all cases. Covering seedlings added little to expense of treatment in our manual applications. Use of shielded spray nozzles or directed applications could also provide similar protection and decrease the possibility of conifer injury. High volumes of water carrier in our spray applications were aimed at enhancing thoroughness and uniformity of herbicide distribution. Lower volumes should differ little in effectiveness.

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Acknowledgment

We gratefully acknowledge the assistance o Thomas F. Beebe, Silviculturist, Wenatchee National Forest, who supervised installation of the study at Entiat River.

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A mixture of dalapon and atrazine consistently controlled grasses and forbs better than either herbicide used alone. Sprayed over and around newly planted ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), the mixture doubled tree survival in one study, greatly enhanced height growth in another, but produced no significant gains in four studies. Protecting seedlings from herbicide sprays proved beneficial in two studies, but seemed unnecessary in four others.

Keywords: Herbicides (-regeneration, grass control, forbs, dalapon, atrazine.

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GPO 992-568